British Telecommunications Engineering

VOL 2 PART 1 APRIL 1983

THE INSTITUTION OF BRITISH TELECOMMUNICATIONS ENGINEERS · NIL SINE LABORE

The Journal of
The Institution of British Telecommunications Engineers

BRITISH TELECOMMUNICATIONS ENGINEERING

VOL 2 PART 1 APRIL 1983

Contents

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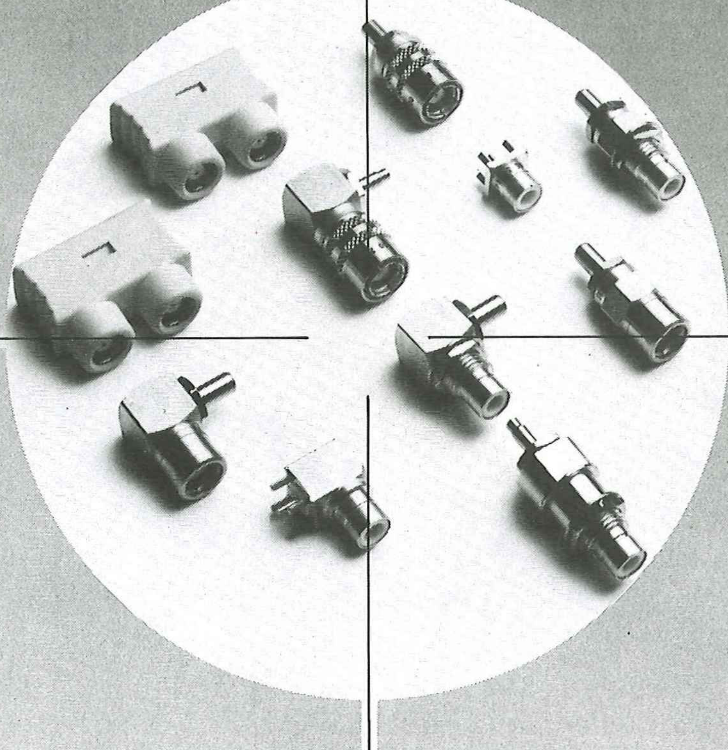

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43/4C	G67244D22	08-03-2BB-B	RG179B/U
Right Angle Crimp Sockets			
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43/2D	G67242D117	08-03-1B2-Q	2002
43/3D	G67242D62	08-03-1B3-R	2003
43/4D	G67242D22	08-03-1BB-B	RG179B/U
Straight Bulkhead Crimp Plugs			
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43/3A	G67245D62	07-02-1B3-R	2003
43/4A	G67245D22	07-02-1BB-B	RG179B/U
Right Angle Bulkhead Crimp Plugs			
43/1B	G67249D280	11-02-B1-C	2001
43/2B	G67249D117	11-02-B2-Q	2002
43/3B	G67249D62	11-02-B3-R	2003
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British Telecommunications Engineering

EDITORIAL

Although this issue of *British Telecommunications Engineering* marks the first anniversary of the new *Journal*, it also represents the 75th anniversary of the founding of the *Journal* as *The Post Office Electrical Engineers' Journal* in 1908.

'The scope of the new *Journal* is wide and liberal. In the matter of descriptive and scientific articles and engineering abstracts it should fill a much felt want, as every one in active service has experienced the difficulty in finding time, even when the means exist, to wade through the English and Foreign professional literature in order to keep abreast of the most modern view.'

But these are the words of Sir John Gavey, first President of the Institution of Post Office Electrical Engineers, in his *Words of Welcome* in that first *Journal* in April 1908; and how apt they still are 75 years later in this age of information technology. As technology advances, whole new areas of concern are presented to the telecommunications engineer. Not only are there new concepts in telecommunication, such as local area networks and multipoint satellite communications, but the traditional services are being provided by radically different techniques which must be integrated into the existing network. Information on the details and the implication of all aspects of these changes is of interest, to a greater or lesser degree, throughout the many and diverse disciplines of telecommunication engineering. Thus, to ensure that the *Journal* serves the needs of its readers in these days of rapid technological development, a balance must be struck between satisfying the specialist on the one hand while not overwhelming the technician in the field on the other.

An article on p.2 of this issue of the *Journal* reflects on how the *Journal* has evolved over the past 25 years to satisfy these changing needs and poses the problem of how the *Journal* might best serve its readership in the future.

British Telecommunications Engineering: The Journal's Organisation and Development Since 1958

P. E. NICHOLS, B.SC., and R. CLARK, B.A.†

UDC 621.39(05)

This article, published to mark the 75th Anniversary of the Journal, reviews the Journal's organisation and development over the past 25 years.

INTRODUCTION

The period that has elapsed since the publication of the 50th Anniversary issue of the *Journal* in 1958* has been one of rapid advancement and fundamental change in the technology and organisation of telecommunications in the UK. The passing of the British Telecommunications Act in 1981 by Parliament has divorced Telecommunications from Postal Services and opened a new era in communications. In turn, the Institution of Post Office Electrical Engineers (IPOEE) has been renamed the Institution of British Telecommunications Engineers (IBTE) and the *Journal* has been retitled *British Telecommunications Engineering*.

Over the past 25 years successive editors of the *Journal* have tried to keep the readership informed of the latest developments in telecommunications and postal engineering; and the attempt to achieve this objective accounts for some of the changes that have taken place in the style, content and editorial organisation of the *Journal*. Of course, the emphasis placed on telecommunications in the new title implies no change of policy: *British Telecommunications Engineering* remains committed to serving the interests of postal engineers as well as telecommunications engineers. As this is the 75th Anniversary issue of the founding of the *Journal*, the editors feel that the time is ripe not only for reviewing the *Journal's* organisation and development since 1958, but for stimulating discussion in the *Journal's* correspondence column on ways in which the format and content of the *Journal* might possibly be improved in the future.

READERSHIP AND CIRCULATION

The *Journal*, which is published quarterly in April, July, October and January, is available by yearly subscription. Most of the *Journal's* subscribers are British Telecom (BT) engineers, though not all are members of IBTE. However, the *Journal* is not, as is too often assumed, available only to BT staff, but to anyone at home or overseas who can afford the cost of a yearly subscription. Indeed, the *Journal* is distributed to subscribers in over 100 countries, ranging from Algeria to Zimbabwe, a fact that may be of particular interest to manufacturers and advertisers of telecommunications equipment.

The *Supplement* is not sold separately, but back issues of the *Journal*, together with the *Supplement*, can be purchased by subscribers and non-subscribers. The editorial staff of the *Journal* encourages subscribers retiring from BT to donate their back issues to the *Journal*, as this helps the sales department to maintain its stock of back numbers, particularly of the rarer and more popular issues, for resale to the general public.

The approximate circulation of the *Journal* since 1958 is shown in Fig. 1. The steep rise in the circulation of the *Journal* between 1958 and 1974 and the subsequent plateau and slight fall between 1974 and 1981 would seem to be explained by the fluctuations in the numbers of engineering staff employed by BT, and by the increased importance generally of telecommunications in the commercial, financial and social life of the country. In addition, the success of the *Journal* could be attributed to the fact that it is one of the few journals specialising in telecommunications and postal engineering that is not published as an in-house journal. Finally, at less than 50p per copy to BT subscribers it represents very good value for money.

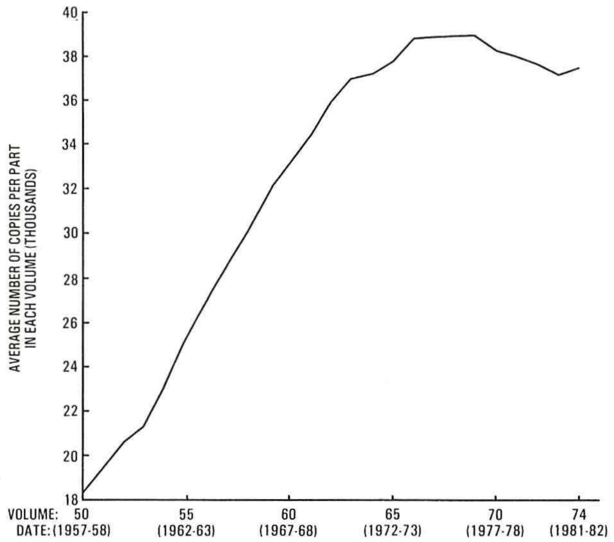


FIG. 1—Circulation of the *Journal*, 1958–1982

EDITORIAL ORGANISATION

The *Journal* is managed on behalf of the IBTE by a Board of Editors, but the Managing Editor is responsible for the day-to-day running of the *Journal*. The Board of Editors comprises a Chairman, who is also the Chairman of the Council of IBTE; a Secretary/Treasurer; 3 co-opted members; 2 members appointed by the Council; the Managing Editor; Deputy Managing Editor and Advertisement Manager. It meets quarterly to discuss the affairs of the *Journal* and to formulate policy.

Prior to 1973, volunteer staff edited the *Journal* on a part-time basis; but the task proved too onerous for editorial standards to be maintained. Consequently, 2 full-time staff, increased later to 3, were appointed. Applicants for the posts of Managing Editor and Deputy Managing Editor are always recruited from the engineering grades of BT and not from the publicity or clerical hierarchies; the content of the articles

†Editorial Office, *British Telecommunications Engineering*

*The Post Office Electrical Engineers' Journal. *Post Off. Electr. Eng. J.*, Apr. 1958, **51**, p. 4.

published in the *Journal* is technical in nature, and it is felt that the editorial management should be controlled by engineering staff.

The *Journal* also employs the following part-time staff: an Advertisement Manager, 2 sales staff, a Secretary/Treasurer and an Assistant Secretary/Treasurer. They are all paid by honorarium, as indeed are 2 other important editorial staff, the Assistant Editors; at present, these posts are filled by former full-time editors of the *Journal*.

Editorial Responsibilities

The need to produce the *Supplement* as well as the *Journal* dictates a natural division of labour in the editorial office. The Managing Editor, in addition to the general management of the *Journal*, commissions and edits most of the principal articles. The Deputy Managing Editor edits the papers for the *Supplement*, the articles submitted by Regions and Areas, the back-end copy (that is, the book reviews, press notices, IBTE notes etc.), and occasionally *Journal* articles, usually when the *Supplement* contains 16 instead of 32 pages.

The members of the editorial staff are not directly involved in the sales or distribution activities of the *Journal*, but are the point of contact for readers' enquiries. Readers should refer to the Notes and Comments section of this issue for details on the distribution arrangements for the *Journal*.

PRODUCTION OF THE JOURNAL

During the past 25 years, the *Journal* has had a change of printer, a change in format and several changes of printing processes.

Since 1938 the *Journal* had been printed by the Baynard Press of Sanders Philips and Co. Ltd., but in 1968 they informed the Board of Editors that for various reasons they no longer wished to print the *Journal*. A new printing contract was placed with the present firm: Unwin Brothers Ltd., The Gresham Press at Old Woking, Surrey. Also with the change in printer, a new page size, page format and cover design were introduced. The same general style is still in use today.

With the April 1975 issue the method of printing the *Journal* was changed from letterpress to lithographic printing so that a cheaper quality of paper could be used. At first, both the *Journal* and the *Supplement* were printed on sheet-fed perfector presses, but at a later date the *Supplement* was transferred to a web-offset machine (see Fig. 2), which uses paper in reel form and is a much quicker method of printing.

In January 1983, further economies were made: the *Journal* was also transferred to web-offset printing and the method of setting the type matter was changed from monotype to a photo-type-setting process. In the new method of composition, operators first type the text from the author's manuscript, together with printing control commands, onto paper forms. These forms are then scanned by an optical-character-recognition reader (see Fig. 3), which produces a magnetic drive tape for a photo-type setter. The final output of the photo-type setter is galleys or pages of text from which the litho printing plates are produced. This new method is used only for setting the text of the *Journal*; the *Supplement* is, for the present, still set in monotype.

As throughout the history of the *Journal*, the editors aim at producing a high-quality publication. This is reflected in the style of the *Journal* and the high standard of printing and illustrations that are used.

JOURNAL CONTENT

The main emphasis of the *Journal* has continued to be the presentation of articles describing the latest developments in all aspects of telecommunications and postal engineering, particularly in respect of the activities of BT and the Post Office.

The articles come from a variety of sources. Most are written at the request of the editors, but a few unsolicited articles are submitted for publication. Virtually all of the authors who write for the *Journal* are from BT or the Post Office, but on occasions articles written by authors from other organisations are published. A few articles of particular interest to the readership are reproduced from other journals or conference proceedings. The editors attempt to achieve a balance in the content and technical level of the articles that meets the needs of readers from all levels and many disciplines.

During the past 25 years, the range of subjects dealt with has been wide, as has the variety of ways in which subjects

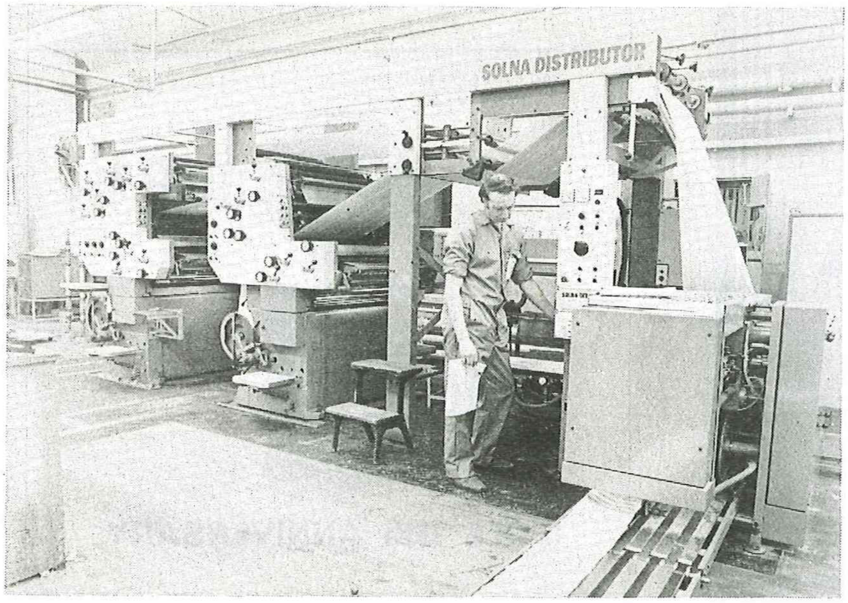


FIG. 2—Web-offset printing press used to print the *Journal*

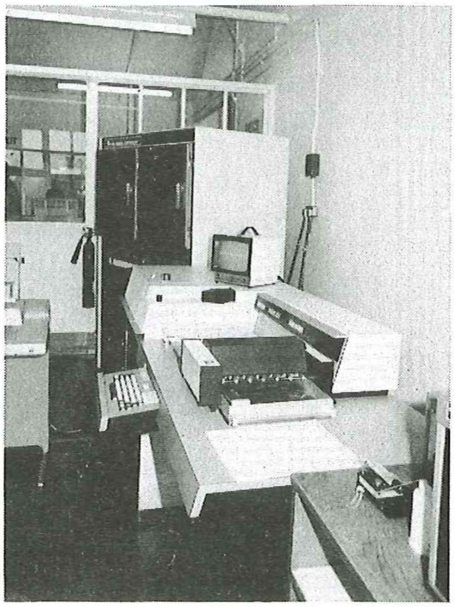


FIG. 3—Optical-character-recognition reader

have been treated. The technical content of many articles has been very deep, and these have been directed more towards the specialist than the general readership. In contrast, there has been a refreshing increase in the number of review articles that have given a much broader appreciation of a particular subject.

Apart from the many articles that have dealt with the design and development of equipment and systems, several articles have been concerned with the managerial aspects of engineering. Articles of historic interest, with a technical flavour, have also been published occasionally; for example, the article entitled *COLLOSSUS and the History of Computing: Dollis Hill's Important Contribution* that appeared in the July 1977 issue (**70**(2)) was of particular interest.

Although the majority of articles has been devoted to developments in telecommunications engineering, several articles dealing specifically with engineering activities in the postal business have been published; for example, letter-post mechanisation and parcel sorting.

Regional Notes

The editors have actively encouraged authors from Regions and Areas to submit articles. Often these articles have been of sufficient length and merit to be published as main articles, but the majority have been published under the collective name of Regional Notes. These articles, which are mainly concerned with field activities, are of interest not only to engineers in other Regions and Areas, but also to research and development engineers. To field engineers they can provide a spark of inspiration for solving local problems; to development engineers they can provide useful feedback on systems in service. Since April 1977, greater prominence has been given to these articles and a similar method of presentation to that used for main articles has been adopted. The editors wish to maintain, if not increase, the number of these articles published and therefore appeal to readers in Regions and Areas to consider whether any activities related to telecommunications in their locality would form the basis for an interesting article.

Press Notices

Since April 1972, a selection of official press notices has been included in the *Journal*. While these notices may have lost topicality by the time they are published in the *Journal*, they do help to give some insight to some of the broader activities of the business. Often they provide a useful introduction to new equipment and services in advance of an article being prepared specifically for publication in the *Journal*. In recent issues, some of the lengthier press notices, illustrated where appropriate, have formed the basis of small feature articles.

Special Issues

During the past 25 years, a number of special issues have been published. The January 1959 issue (**51**(4)) was devoted entirely to articles on subscriber trunk dialling to mark its inauguration in the UK by Her Majesty the Queen on 4 December 1958. A further special issue, published in October 1973 (**66**(3)), was devoted to articles on BT's 60 MHz frequency-division-multiplex transmission system. Between January 1979 and April 1981, a series of 26 articles on System X was published in the *Journal*. This series has since been reprinted as a single book, and placed on general sale; the book has proved to be very popular, and so far some 6500 copies have been sold.

Of particular note was the October 1981 issue (**74**(3)), which was a special issue to mark the 75th Anniversary of the IPOEE. The issue, which contained double the average number of pages, several being in full colour, featured articles that reviewed the changes that have taken place in

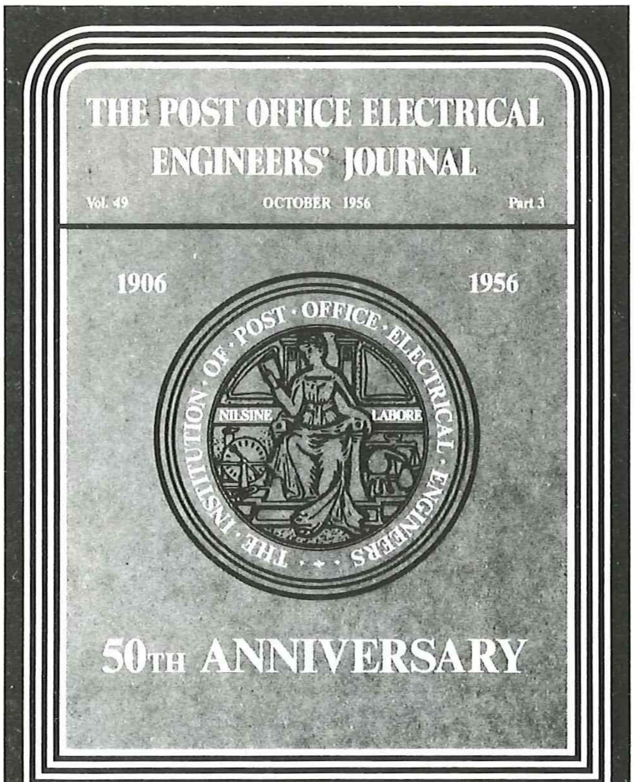


FIG. 4—Cover design for the IPOEE 50th Anniversary issue

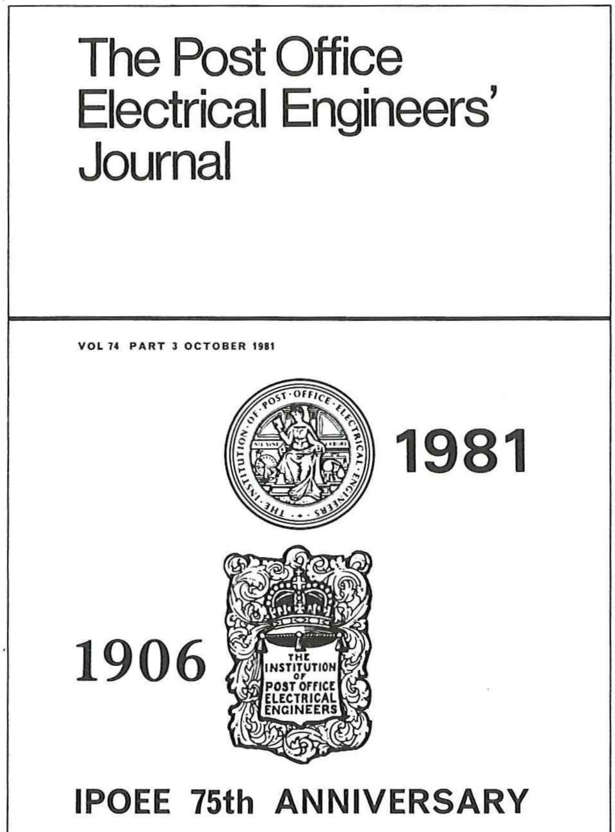


FIG. 5—Cover design for the IPOEE 75th Anniversary issue

telecommunications and postal services over the past 25 years and speculated on future developments. An article describing the development of the Institution since its foundation in 1906 was also included. This edition provides a wealth of reference material and, together with the special issue that was published in October 1956 to mark the 50th Anniversary of the Institution, forms a valuable record of the history of telecommunications and postal engineering. The covers of these 2 issues are reproduced in Figs. 4 and 5.

SUPPLEMENT

The *Journal* has continued to provide material of particular interest to students, through the *Supplement*, with a break only for the IPOEE 75th Anniversary issue; the additional editorial work created by that issue did not allow the *Supplement* to be published. Up to January 1978 the *Supplement* was devoted entirely to supplying model answers to questions set in City and Guilds of London Institute's (CGLI's) examinations for subjects in the Telecommunications Technicians course. Since then, the *Supplement* has also included similar material catering for students studying certain Technician Education Council units at Certificate level. Students studying these courses are assessed by colleges and no national examinations are set. The *Supplement* has tried to help students on these courses by providing typical questions set in styles that they might meet in assessments, together with model answers. In addition, material for some Scottish Technical Education Council subjects has been included. The amount of material covering CGLI subjects has steadily been reduced and in April 1982 it was ceased entirely.

As an experiment, a reprint of one of BT's series of *Educational Pamphlets*, entitled *Field-Effect Transistors*, was included in the October 1982 issue of the *Supplement*. The editors considered that educational papers dealing with telecommunications-related topics at a basic level would complement the articles in the *Journal* and the question/answer style of material in the *Supplement*. A questionnaire in which readers were asked to give their views on further similar papers being published was also included. When considered in terms of the total readership of the *Journal*, the number of questionnaires returned was small, and it has not been possible to assess how popular this proposed service is likely to be. However, virtually all of the readers (485 at the end of January 1983) that replied responded encouragingly. The editors have, therefore, decided to continue the experiment by publishing one or two more papers of a similar style in forthcoming issues of the *Supplement*.

One interesting result that came out of the survey was the range of subjects which readers said they would like to see in the proposed series of articles. A list of 18 suggested topics was printed in the questionnaire and readers were asked to indicate those which they would like to see covered; the results for this question are shown in Fig. 6. Readers were also asked to list their own ideas for subjects. The replies indicate that there seems to be a need not only for more information on modern systems and technology to help readers keep up-to-date, but also for information on more fundamental topics (as indicated by the results for 'basics of electronic circuits'), perhaps to help refresh forgotten knowledge. Some of the comments on this scheme written by readers in the questionnaire are reproduced in the Notes and Comments section of this issue of the *Journal*.

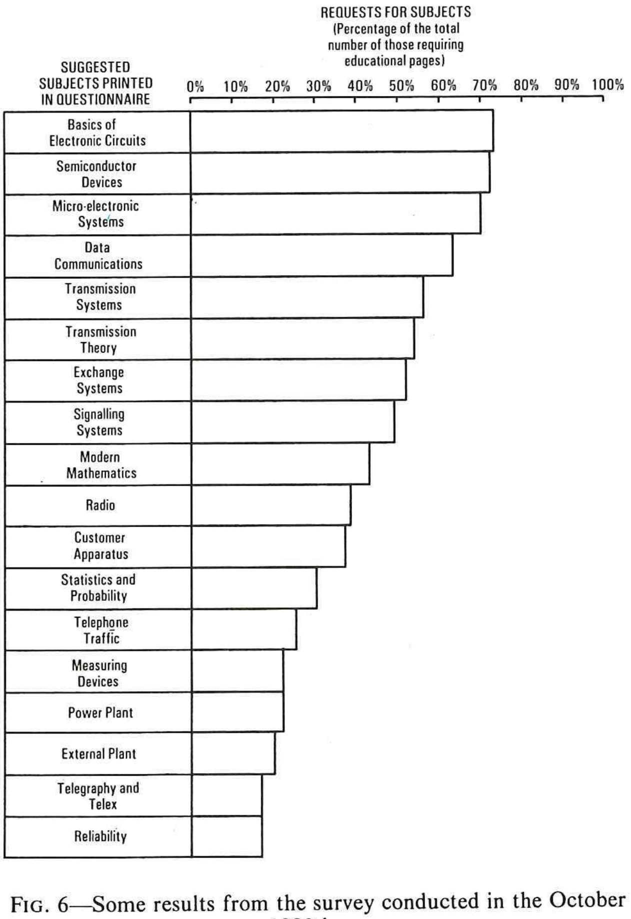


FIG. 6—Some results from the survey conducted in the October 1982 issue

SERVICES

One important service provided by the *Journal* is the publication of an annual index, which is printed as a 4-page loose insert and included with the final part of each volume. The index gives the contents of that volume in the form of an alphabetical list of authors and keywords from each title. Searching for articles on a particular topic over several volumes is inconvenient; therefore, from time to time, complete indexes covering several volumes have been published. The last such complete index published was for volumes 51–60 of the *Post Office Electrical Engineers' Journal (POEEJ)* but, at present, the Board of Editors has no plans to publish further complete indexes because of the prohibitive cost. However, volumes 61–74 of the *POEEJ*, together with *British Telecommunications Engineering*, are steadily being indexed on a small business computer. When this work has been completed, it will be possible to carry out searches on behalf of researchers or even offer complete indexes on floppy disc or as a print-out.

Reprints of single articles or groups of articles, say for use as handouts at exhibitions and seminars, can be ordered through the editorial office.

THE FUTURE OF THE JOURNAL

The Board of Editors is keen to ensure that the *Journal* meets the readers' requirements of a technical journal. To this end, readers are invited to write to the Managing Editor and express their views on the content and format of the *Journal* and the *Supplement*, or indeed on any aspect of the operation of the *Journal*, and suggest ways in which they would like to see the *Journal* develop in the future. It is hoped that this invitation will stimulate a continuing discussion within the pages of the *Journal*, not just on matters relating to the *Journal*, but also on engineering matters in general. Letters should be sent to the Managing Editor, *British Telecommunications Engineering*, IDP 5.1.1, Room 704 Lutyens House, 1–6 Finsbury Circus, London EC2M 7LY.

Local Area Networks

M. G. ROWLANDS, B.SC., PH.D., C.ENG., M.I.E.E†

UDC 681.3

This article presents an introduction to local area networks, giving a description of Ethernet, the Cambridge Ring and token-passing systems, as well as broadband networks.

INTRODUCTION

A central computer to which a variety of peripherals, including terminals, can be directly attached has been a common means of providing data processing facilities. However, this traditional solution is not appropriate now that the trend is towards distributed computing with a variety of smaller machines, including individual work stations, which need to interwork so that resources such as data or printers can be shared by all users. Local area networks (LANs) have been developed to fulfil this interworking requirement by offering potentially low cost, reliable and fast communications between processors and peripherals, thereby facilitating resource sharing over the network. LANs are, therefore, of considerable importance for future developments in data processing, process control and the office-of-the-future environments.

At present, LAN installations are mainly private, being used to interconnect existing or new equipment owned and used by organisations on their own premises. By comparison with the scale of British Telecom's (BT's) national network, the area covered by a LAN is small. Currently, a LAN is typically located within a single site or building and operates over a distance generally between 0·1 km and 10 km, but, using broadband techniques, this distance can be extended to 50 km. By means of a gateway, a LAN can interface to any other network; for example, it can be linked to another LAN or, alternatively, to BT's network.

For the typical LAN, error rates are low and data rates are high. The LAN protocols can, therefore, be designed straightforwardly by regarding bandwidth as plentiful and transmission errors as negligible. This is in marked contrast with the national network where error rates are much higher and there is a requirement to make maximum use of the available bandwidth. Data can be successfully transmitted in the local area using techniques that would not work for current long-haul transmission.

Over the past few years a number of new technologies have been developed to interconnect computers and their peripheral devices using different transmission media, topologies and access techniques. For example, some LANs use coaxial cable while others use twisted-pair cable, some have a ring topology while others use a bus. A variety of different access techniques such as *carrier sense multiple access* (CSMA) with or without *collision detection* (CD), *empty-slot* and *token-passing* techniques has evolved. This article discusses the Ethernet development, which is an example of a CSMA/CD coaxial cable bus, the Cambridge Ring, which is an empty-slot system, and token-passing techniques. Broadband LANs, where the available bandwidth is divided into a number of independent channels, are also described. The private branch exchange (PBX) can also be developed to fulfil a type of local area networking function, but this is not within the scope of this article.

† Research Department, British Telecom Major Systems

THE ETHERNET DEVELOPMENT

Ethernet is the LAN developed initially by Xerox in the early-1970s. Latterly, both Digital Equipment Corporation (DEC), with their computer interest, and Intel, who intend to manufacture Ethernet chips, have joined with Xerox in a joint venture designed to promote the standardisation of the Ethernet CSMA/CD technique. In 1980, the specification for the 10 Mbit/s baseband CSMA/CD Ethernet system was published[1], and a number of companies now offer components which meet the Ethernet specification. Ethernet has thus become well-established commercially and a strong contender in the international standards forum.

Topology

Ethernet is a baseband bus system in which the signal is directly modulated on to the transmission medium. It uses a passive coaxial cable commonly called its *Ether* as its transmission medium. Each station is connected to the Ether via an interface cable to a transceiver which taps into the cable using community antenna television (CATV) techniques. The transceiver must be adjacent to the cable tap, but the interface cable may be as long as 50 m. This gives sufficient flexibility to allow equipment attached to the network to be moved, without having to reroute the coaxial cable.

An Ethernet is built up from segments of cable, each of which must be terminated in its characteristic impedance at both ends. Each segment may have a maximum of 100 stations and be up to 500 m in length. Each segment of the cable is marked at 2·5 m intervals and, to avoid unwanted reflections, stations should only be connected at these points. Fig. 1 gives a minimal configuration for one segment, showing these limitations.

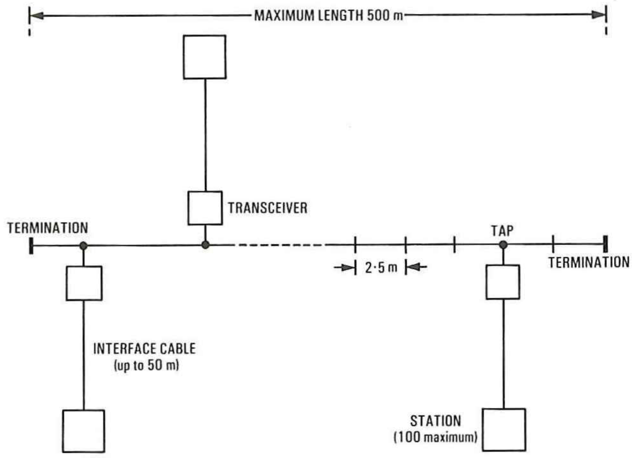


FIG. 1—A single segment Ethernet configuration

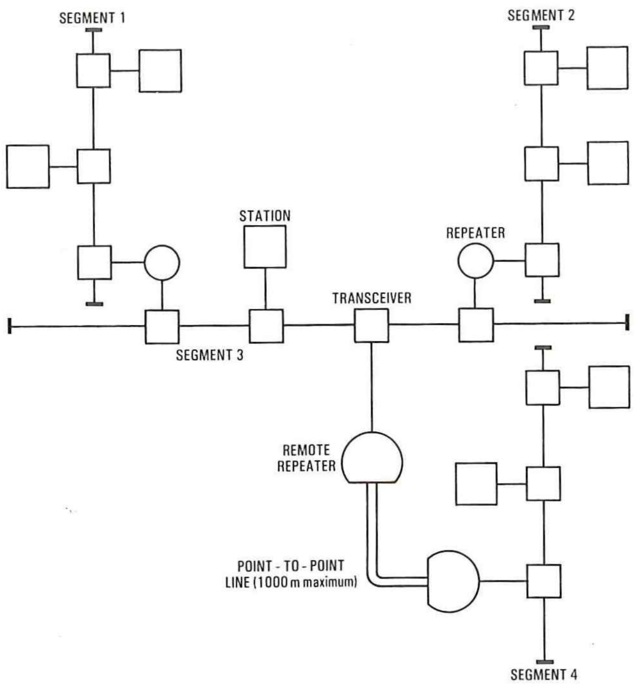


FIG. 2—A multi-segment Ethernet installation

DESTINATION	6 octets
SOURCE	6 octets
TYPE	2 octets
DATA	46-1500 octets
FRAME CHECK SEQUENCE	4 octets

FIG. 3—Ethernet packet format

Segments are linked together by repeaters as shown in the typical large-scale installation of Fig. 2. Repeaters may be attached at any transceiver point, not necessarily at the end of the cable. A maximum of 1000 m of point-to-point link may also be included in the system, thereby allowing the linking of cable segments in different buildings. Each station must be connected to every other station through only one path which contains, at most, 2 repeaters. The maximum cable distance between furthermost stations is therefore 2·5 km.

Transmission over Ethernet

Control of the Ethernet is distributed among the stations and each station captures the network when it requires to send data. The network uses the CSMA/CD scheme for coping with simultaneous attempts to capture the network (contention). If a station requires to use the network, it must first determine whether the Ethernet is in use. Should the network be busy, then the station must wait until the network is clear before attempting transmission. When the Ethernet is free, the station transmits its information and the signal propagates along the bus so that all other stations become aware of the signal, although clearly there is a time delay between a station establishing transmission and all other stations recognising the transmission. During this time interval, a second station may begin to transmit in contention and a data collision results. To cope with this problem, each transmitting station compares the *send* and *receive* signals, and flags any discrepancy as a collision. When a transmitting station detects a collision, it ceases transmission of the data and sends a *jamming* signal to ensure that all other interested parties are aware of the collision. An algorithm (the binary exponential back-off algorithm[1]) is then invoked at each transmitting station to determine when each should try to transmit again.

Each station may make a total of 16 attempts before transmission is abandoned and an error is reported. As the number of collisions increases because of heavy traffic on the network, so the back-off delay tends to increase in an attempt to reduce the peak congestion.

If the network is free, a station begins its transmission by sending a 64 bit predetermined sequence for preamble which is used for channel stabilisation and synchronisation. When encoded, the preamble pattern appears as a periodic waveform on the cable at a frequency of 5 MHz. Transmission of the data packet follows, the packet format being shown in Fig. 3.

Addresses are 48 bits in length and can be either physical or multicast. The physical address is unique, being associated with one particular station on the world-wide Ethernet; its allocation being controlled by Xerox, which aims to keep every station on every Ethernet unique so that, in principle, any Ethernet station can communicate with all other Ethernet stations. The multicast address denotes a multi-destination address associated with one or more stations on a particular Ethernet. For example, the multicast group address may refer to a group of logically related stations, while the broadcast address refers to all stations on the particular Ethernet. The first bit of the 48 bit address distinguishes physical from multicast addresses.

The type field consists of 2 octets reserved for use by the higher-level protocols. Specification of the position and size of the type field allows multiple higher-level protocols to share the same Ethernet network without conflict.

The data field can contain between 46 and 1500 octets inclusive, with no restriction on the sequence of octet values appearing in the data field. The frame check sequence contains a 32 bit cyclic redundancy check (CRC) value computed from the contents of the source, destination, type and data fields.

Although the protocols described in the Ethernet specification ensure that the transmitting station will try up to 16 times to transmit a packet, there is no guarantee of successful reception by the intended receiving station(s). Any further check to ensure that transmissions are indeed received must be built into the higher layers of protocol.

The Ethernet CSMA/CD system is now well established commercially (particularly since the publication of the 1980 Ethernet specification) and it is likely to become an internationally accepted standard. This is encouraging designers to produce Ethernet-compatible equipment. Now that the function is specified, a number of integrated circuit manufacturers are making Ethernet controller chips, the first of which are expected to be available early in 1983 and should bring about a significant reduction in the price of connection to Ethernet. In addition, interfacing to a wide variety of different machines is encouraged by standardisation. Already a number of companies (such as Zilog with Z-NET and Sintrom with Perinet) regard Ethernet as the standard network to which their own existing networks must interface. All these movements are welcome simplifications in the complex LAN picture, but there is now a need to standardise on higher layers of protocol.

User experience suggests that the Ethernet is reliable and rarely fails, but, when it does, it is often difficult to find the fault because it is generally an analogue problem caused by reflections interfering with the transmitted signal.

The CSMA/CD technique does not give a guaranteed minimum bandwidth for each station. This means that

TABLE 1
Characteristics of some Local Area Networks

Network	Speed (Mbit/s)	Medium	Topology	Access Method
Arc	2·5	coaxial cable	bus	Token passing
Cambridge Ring	10	twisted pair	ring	Empty slot
Cluster/ One-	0·24	16-wire cable	bus	CSMA
Domain	12	coaxial cable	ring	Token passing
Econet	0·21	4-wire telephone cable	bus	CSMA
Ethernet	10	coaxial cable	bus	CSMA/CD
Internet	1	coaxial cable	bus	CSMA/CD
Net/One	10	coaxial cable	bus	CSMA/CD
Omnilink	0·04	coaxial cable	ring	Token passing
Omninet	1	twisted pair	bus	CSMA
Planet	10	coaxial cable	ring	Empty slot
Primenet	10	coaxial cable	ring	Token passing
Z-net	0·8	coaxial cable	bus	CSMA/CD

real-time applications such as process control or speech are difficult to implement.

In the wake of the Ethernet development, a variety of cheaper systems has evolved which economise by not adhering to the Ethernet specification. For example, Omninet and Cluster/One each use CSMA techniques but do not implement collision detection. A variety of CSMA and CSMA/CD networks operate at lower speeds than the 10 Mbit/s of the Ethernet specification to ease their low-cost implementation, and not all systems use coaxial cable. For example, Omninet uses twisted-pair cable and operates at 1 Mbit/s, while Cluster/One uses a 16-wire cable and operates at 240 kbit/s. Z-NET operates at 800 kbit/s and uses coaxial cable that does not meet the Ethernet specification. A summary of the characteristics of some of the networks that are related to Ethernet, but which differ in significant detail, is shown in Table 1.

THE CAMBRIDGE RING DEVELOPMENT

The Cambridge Ring was developed in the Cambridge University Computing Laboratories[2] as a method of interconnecting a wide range of computers and similar devices at data rates in excess of those available using conventional telecommunication techniques. The Cambridge Ring LAN is based on the circulating empty-slot principle. Mini-packets circulate round the ring and, when seized by transmitting stations, move data bit serially around the ring at 10 Mbit/s.

Topology

As illustrated in Fig. 4, the transmission medium links a series of repeaters in a ring configuration. The transmission medium may be ordinary telephone cable, coaxial cable or optical fibre, and the repeater spacing is dependent on the chosen medium. Most of the present installations use telephone cable and have repeater spacings in the range 100–300 m, but repeater spacings of 2 km have been achieved using optical-fibre cables. Each repeater can be connected to a station which, in turn, is connected via

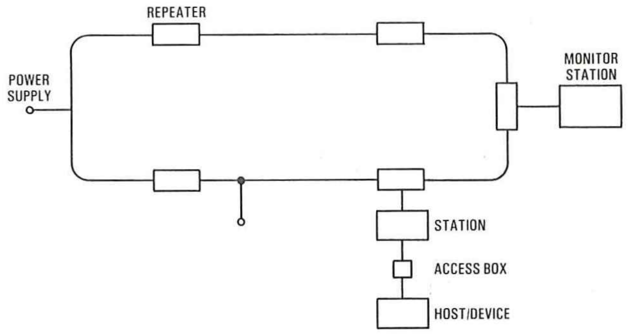


FIG. 4—The Cambridge Ring

multi-core cable to a specially designed access logic which interfaces to the host. The access logic is normally intelligent for simple hosts, but may be a simple interrupt-driven interface for the more sophisticated host. Because the less intelligent access logic places a greater software demand on the host, it should be adopted only when the host is capable of coping with the demand.

The monitor station sets up the mini-packet structure during TURN-ON, monitors the ring, clears corrupted mini-packets and keeps some error statistics. In addition, an error logging station can be situated immediately before the monitor station for the purpose of receiving error information sent both from the monitor station and active ring stations.

Transmission over the Cambridge Ring

When a station wishes to transmit data, it must first seize an empty mini-packet. If the first mini-packet to arrive is full, then the station must wait until an empty mini-packet arrives. The mini-packet is then marked as FULL and the data is transmitted. When the next station receives the full mini-packet, it considers whether it wants to receive the mini-packet. A mini-packet that does not bear the station's own address as the destination continues to the next station. If the mini-packet does bear the station's own address, but the station cannot cope with the mini-packet at this time then the station marks the mini-packet accordingly and the mini-packet continues to the next station. A station that can cope with the data effectively copies the data and marks the mini-packet as ACCEPTED, while the mini-packet continues round the ring to the next station. When the originator receives the mini-packet, it marks it as EMPTY by resetting the *full/empty* bit. The empty mini-packet is then sent to the next station downstream to give it an opportunity to transmit. In this way, hogging of the ring by one particular station is prevented. From the returned packet, the originator knows whether the intended recipient has accepted the data, and can then either try again later or carry on with the next task as appropriate.

The mini-packet format shown in Fig 5, has been chosen to allow the maximum timing tolerance and minimum delay at the transmitter and receiver. The leading bit, the *start* bit, is always a 1 and indicates the start of the mini-packet. The following bit (Bit 2) is the *full/empty* bit which, when set to 1, denotes a full mini-packet.

The *monitor* bit (Bit 3) is used to prevent mini-packets circulating indefinitely. The transmitting station sets the

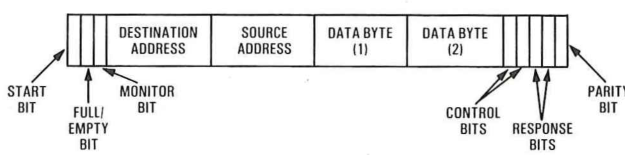


FIG. 5—The Cambridge Ring packet format

monitor bit when it transmits a full mini-packet. On receiving that mini-packet, the monitor changes the *monitor* bit to 0. If the monitor station receives a full mini-packet with the *monitor* bit already 0 the packet is presumed to have circulated the ring more than once. The monitor station then empties the mini-packet thereby making it available for use by other stations. If the monitor receives a mini-packet with the *full/empty* bit 0 and the *monitor* bit set, then the monitor assumes that the mini-packet should be marked FULL. The monitor therefore changes both the *full/empty* bit and the *monitor* bit. If the assumption is incorrect, the mini-packet circulates the ring and returns to the monitor station with its *monitor* bit already 0 and is then emptied.

The next 2 octets indicate the destination and source addresses. The values 0 and 255 are dedicated for use by the station source select register (SSR), while the remaining 254 possibilities can be used as ring station addresses. When the station is willing to receive from any source the SSR is set to 255 (FF hexadecimal). If it is set to any other number, then the station is willing to take data from only the specified source. If it is set to 0, the station ignores packets from all sources. The only exception is the logging station, which is designed to accept all packets with 0 in their destination address.

The data follows in 2 octets. The mini-packet of Fig. 5 shows 2 *control* bits which would be present in the 40 bit mini-packet; however, at this point in time, the role of these *control* bits has not been defined. The great majority of the Cambridge Rings in use have a 38 bit mini-packet without these 2 *control* bits.

The *response* bits are used to indicate to the transmitting station whether or not the returning mini-packet has been accepted. On transmission, the originator sets the *response* bits to 11. If the mini-packet returns with the *response* bits unchanged, then the receiving station has ignored the transmission. A mini-packet which has been accepted by the receiving station returns with its *response* bits set to 01. If the receiving station's SSR is set to 0 so that the station is not receiving anything, then the *response* bits are set to 10; that is, unselected. The receiving station's SSR may be set to the address of a different station, not the intending transmitter, in which case the receiving station indicates that it is busy by setting the *response* bits to 00. When the transmitting station receives its mini-packet marked UNSELECTED, BUSY or IGNORED the station first waits for 2 ring delays before trying again. In this context a ring delay is the time taken for a mini-packet to go completely round the ring. If the transmission is still unsuccessful, the station must wait for 16 ring delays between subsequent attempts.

A simple single-ring installation will cease operating in the event of a repeater failure or severance of the cable. Several ways of improving the ring reliability have been suggested. For example, the star-connected ring shown in Fig. 6 overcomes the problem of repeater failure or broken cable by means of repeater by-pass relays which are kept at some central location. When a cable is broken or a repeater failure is detected, the whole section of cable is readily removed without problems being caused with the maximum distance allowed between repeaters. The maximum distance from the centre of the ring is half the maximum distance between repeaters and this could be a limitation in some circumstances. If a ring is using high-quality coaxial cable or optical fibres, then there are unlikely to be problems with the maximum distance between repeaters. Other techniques for improving ring reliability involve duplication of cabling and/or repeaters with the associated extra cost. With one exception, none of the current manufacturers provide systems which give back-up for failure. Although users of the 100 or so UK Cambridge Ring systems report very few problems with their rings, the majority of installations have readily available technical expertise to solve any problems encountered. Evidence, again from users, is that errors are negligible and when they do occur the simple checks provided by the system can retrieve the situation.

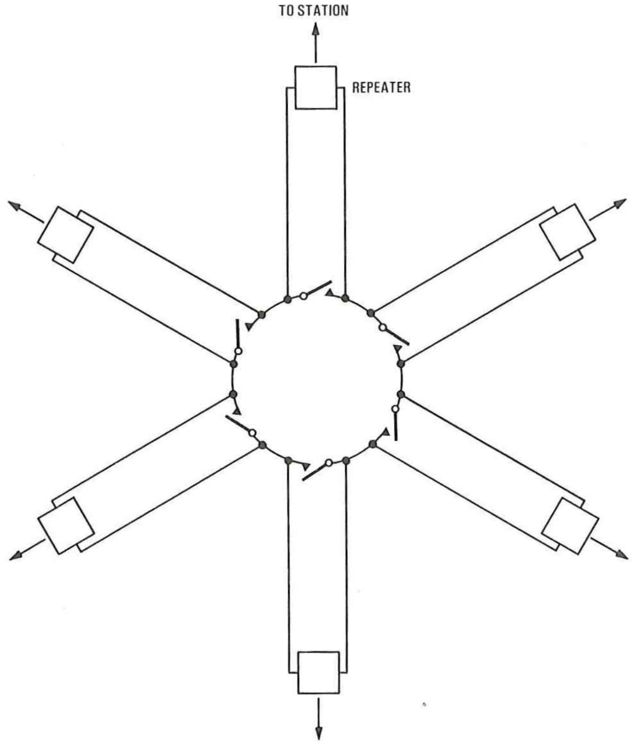


FIG. 6—The star-connected ring

Future developments include increasing the data rate towards 100 Mbit/s and manufacturing Cambridge Ring chips.

TOKEN-ACCESS TECHNIQUES

The token-access technique has been adopted in both ring and bus LANs. For example, IBM's experimental network in its Zurich Research Laboratories[3] is a token-passing ring while Datapoint has adopted a token-passing bus to create its attached resource computer (ARC) system. Some parameters of token-passing networks are shown in Table 1.

To illustrate token-access techniques, the operation of a token ring is described. A token circulating round the network denotes that the network is FREE. A station wishing to transmit essentially removes the token, transmits its data and restores the token to show that it has ceased transmitting and the network is again FREE. For each network, the token is a specific bit pattern that must never be allowed to occur in the data. The token could, for example, be a series of *ones* in which case the technique of bit stuffing may be used to prevent the same sequence of *ones* from arising in the data. When the station seizes the token, it could then invert the final 1 to remove the token. A station looking for a token must therefore copy, store and retransmit each potential token bit except the final one. When the final bit has been read then, if the sequence of bits matches the token, the final bit is inverted before transmission. The 2 operating modes for a ring interface are TRANSMIT and LISTEN. In LISTEN mode the bits received from the ring are copied back out on to the ring after a 1 bit delay. Only after the token has been seized can the TRANSMIT mode be entered thereby allowing the station to transmit data, followed by the regenerated token on to the ring. Bits which have circulated once around the ring are removed by the sending station, which may then either discard them or store them to compare with the original data for checking purposes. When the last bit of data has been received and removed by the sending station, the ring interface must immediately switch back to the

LISTEN mode so that the following token or packet is not removed.

When a station has seized the token it could, in principle, be allowed to send all data that is ready for transmission at that time. In practice, however, the amount of data is restricted so that a particular station does not hog the network. For example, a proposed IEEE recommendation states that each station is only allowed to send one packet before restoring the token to give the next station downstream an opportunity to transmit data. Thus possession of the token progresses logically round the ring.

Token-passing techniques are being studied by the IEEE Project 802 standards committee on LANs. IBM is a major force in this area and, as the company is now firmly committed to token-passing ring technology, it could well end up by effectively setting the standards itself. IBM has submitted several papers describing its system for consideration by the IEEE 802 committee.

BROADBAND SYSTEMS

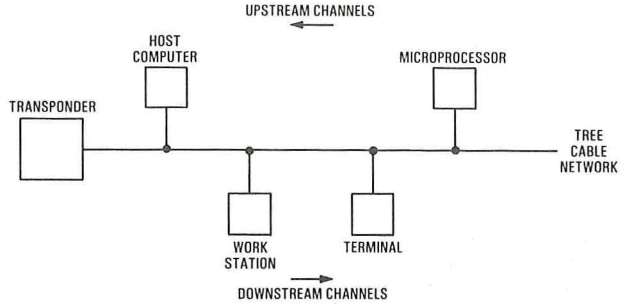
Combining some of the principles familiar in telephony with the newer techniques of the LANs previously described gives the broadband class of LANs. Frequency-division multiplexing (FDM) is used to divide the total available bandwidth into smaller frequency bands, each of which can then be used independently. Broadband systems offer multiple independent channels that can be used to provide different services such as speech or video, as well as data. For example, one channel could be used for dedicated private circuits using fixed frequency modems, while another channel could be devoted to switched circuits using frequency-agile modems. Alternatively, a channel may adopt the principles of CSMA/CD or token passing, although the realisation is somewhat different from that of the baseband systems.

Development of the domestic cable-television networks in the US has led to a large industry with mass production of the necessary components. For broadband LANs, the frequency bands chosen for the initial FDM split are, therefore, normally related to those used in cable television to capitalise on this source of economic components. Those components suitable for the LAN environment include:

(*a*) cable,
(*b*) transponders,
(*c*) taps,
(*d*) splitters,
(*e*) attenuators,
(*f*) terminators, and
(*g*) amplifiers.

Strictly, for cable television distribution, it is only necessary for the network to work one-way. However, much publicity has been given to the new possibilities opened up by the bidirectionality of such systems. In the late-1970s, a 2-way cable facility was introduced in Columbus, Ohio, whereby subscribers from about 30 000 homes could participate in instant polls by means of RESPONSE buttons on their channel-selector units. The concept can also be extended to provide services such as shop-at-home, bank-at-home or, alternatively, home security incorporating fire alarm, burglar alarm and medical alert systems. Bidirectional operation can be achieved either by using sets of components which will operate on both upstream and downstream signals on the same cable or by installing a dual cable. When a single cable is used, the upstream and downstream signals are allocated to different frequency bands (each consisting of several channels).

A block diagram of a broadband network is given in Fig. 7. Whether a single- or dual-cable approach is used for bidirectionality, a transponder must be located at the head-end of the network. The function of the transponder is to accept one or more upstream bands and retransmit all received (analogue) signals as downstream bands. If a dual-cable system is used, no frequency translation is needed. For a single-cable system, the transponder filters and translates the incoming 6 MHz bands into the appropriate outgoing frequencies. By choosing to abide by the cable-television conventions for upstream and downstream spectral allocations, LAN manufacturers may make use of standard cable-television transponders.



Note: The transponder accepts the upstream channels and retransmits as downstream channels

FIG. 7—Block diagram of a broadband LAN

Operation of a broadband LAN is clearly critically dependent on the head-end equipment. This, however, can be duplicated at low cost, and automatic self-test and change-over can be provided.

A broadband LAN system is physically a tree network, although for each frequency band the topology might be a different tree because of the selected band-pass characteristics of some components; for example, a component might be chosen to prohibit certain bands on one of its branches.

By exploiting the bandwidth of the cable, broadband systems can offer a greater throughput capability than the baseband systems, but at the expense of greater complexity. Coaxial cable broadband systems can also operate over greater distances—a range of 50 km is feasible for a broadband network, whereas for a single Ethernet the maximum range is only 2·5 km.

Broadband techniques could, in the future, be used for an integrated services wideband network which provides all services such as cable television and videotex and gives access to networks such as Packet SwitchStream (BT's packet-switched service) as well as fulfilling a LAN role. Although the tree/branch topology structure described above is unlikely to provide sufficient bandwidth for such a comprehensive service, a multi-star configuration such as that shown in Fig. 8 could be used. In the multi-star network, groups of customers are individually connected by wideband links to wideband switch units, which are then connected to the

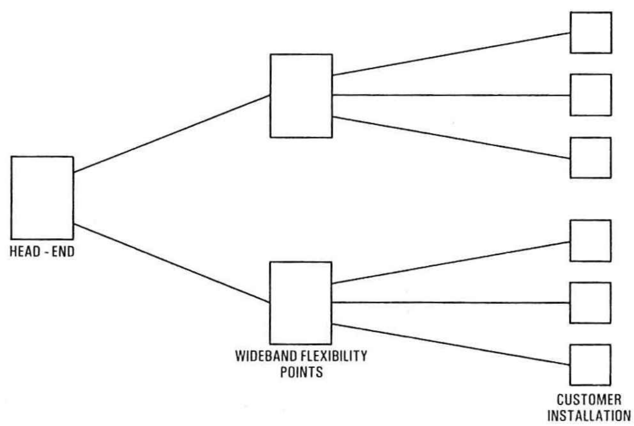


FIG. 8—A multi-star integrated services wideband network

head-end by trunk circuits. The customer, therefore, has the full bandwidth available while economies can be made by concentrating traffic between the wideband switch units and the head-end.

DISCUSSION

The preceding sections have described the bit transport mechanism for a variety of different networks. While the standardisation work on LANs is still in its infancy, good progress is being made in standardising the bit transport mechanisms. In the US, the IEEE 802 committee is considering protocols for both CSMA/CD and token-passing LANs while in the UK the FOCUS committee set up by the Department of Industry will accept responsibility for LAN standardisation. Meanwhile, the Ring Advisory Group (RAG) under the auspices of the Joint Network Team (JNT) has completed work on the formulation of standards for the Cambridge Ring. In addition, the European Computer Manufacturers Association (ECMA) has produced a document that is the European contribution to the IEEE 802 committee. The document deals initially with the 10 Mbit/s CSMA/CD system, but standards for the other technologies are expected to follow. The commercial pressure behind Ethernet has ensured that the Ethernet 10 Mbit/s CSMA/CD system is at least very close to the standard if not identical to it. Similarly, now that IBM is interested in token-passing rings, it is expected that it will strongly influence the standard eventually reached for token-passing networks.

Even when the bit transport mechanisms have been standardised, full communication is not possible without the implementation of higher-level protocols. It is in this area where effort is necessary now. In order for any of the networks listed in Table 1 to work, higher-level protocols must be implemented and, in general, these are currently application/implementation specific. Clearly, higher-level protocol implementations do exist and, no doubt, examples such as the Xerox higher-level protocols will form a useful input to the various standards committees. However, to achieve standardisation of higher-level protocols, much effort is still required.

ACKNOWLEDGEMENT

Acknowledgement is made to the Director of Research of British Telecom for permission to make use of the information in this article.

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Book Review

Broadband Feedback Amplifiers. D. J. H. Maclean. John Wiley and Sons Ltd. xxviii+295pp. 90 ills. £14·75.

This book is the first in a series intended to disseminate rapidly the results of contemporary research in the field of circuits and systems; it is perhaps fitting that this volume on broadband feedback amplifiers should begin the series.

The design, modelling and realisation of wideband amplifiers spanning high frequency (HF), very-high frequency (VHF) and ultra-high frequency (UHF) are topics fraught with theoretical and practical limitations. It is therefore refreshing to read a book that addresses this difficult topic from the standpoint of that which is practically useful to today's system designer. In his presentation the author has managed to provide some interesting historical perspectives on the early work of Black, Nyquist and Bode; he also adds novelty to his review of the standard design concepts of loop gain and stability margins in single and multi-loop configurations.

From a circuit designer's point of view the key contribution of this book lies in the author's in-depth presentation of a new technique for assessing amplifier stability margins. This technique, denoted by the author as the *embedding network method*, has been developed from a consideration of Bode's feedback theory and the practical measurement of S parameters. As this method requires measurements to be performed on some portion of an amplifier, with a terminating element removed, it provides a true picture of circuit performance and takes account of strays and those largely indefinable departures from theoretical prediction encountered at the higher frequencies.

Sensitivity analysis, noise considerations, microwave amplifiers, feedback in almost linear amplifiers and transimpedance amplifiers for optical receivers are among the other topics briefly considered in the book. In addition, a consideration of the embedding network method in the context of present linear integrated-circuit (IC) developments highlights a probable area of difficulty with the technique. It is not easy to see how it can be straightforwardly extended to IC technology without significant errors of measurement in the VHF and UHF ranges being incurred. However, this does not detract from the usefulness of the technique in discrete circuits, and in the development of prototype circuits, but it could be that computer simulation for IC manufacture will become sufficiently accurate to negate this requirement.

This book is, of necessity, principally one for the specialist, but it should also be of interest to those working in the general field of system design. The author maintains a lucid style throughout the book and embroiders the topics with minimal mathematics, which is pitched at graduate level and leans heavily on matrix manipulation.

P. COCHRANE

Testing Packet-Switched Networks

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UDC 621.394.4: 681.32

This article outlines the problems of testing packet-switched networks and describes the AUTOFLOOD tester developed for this purpose. This article is based on a paper presented at the International Computer Communication Conference, London, in September 1982.

INTRODUCTION

British Telecom (BT) has been involved with packet switching since 1973, initially with the experimental packet-switched service (EPSS), and then with Euronet and BT's international packet-switched service (IPSS). In 1981, BT opened a national public network (Fig. 1), known as the *packet-switched service* (PSS).

The general principles of packet switching have been described elsewhere[1], but it is worth highlighting the PSS system which opened service as a 9-node network covering the whole of the UK; the system has since nearly doubled. Each node contains one or more packet switches, based upon a multiple microprocessor architecture, with each switch capable of handling up to 128 ports. The system is controlled by a network management centre (NMC), based on duplicated minicomputers, each with 600 Mbytes of disc storage. In addition to packet terminals, the system handles character-mode terminals, using its built-in packet assembler/disassembler(PAD).

This article is concerned with the testing problems posed by the implementation of packet-switched networks, the development of a test tool to overcome these problems, and the experiences in testing the PSS.

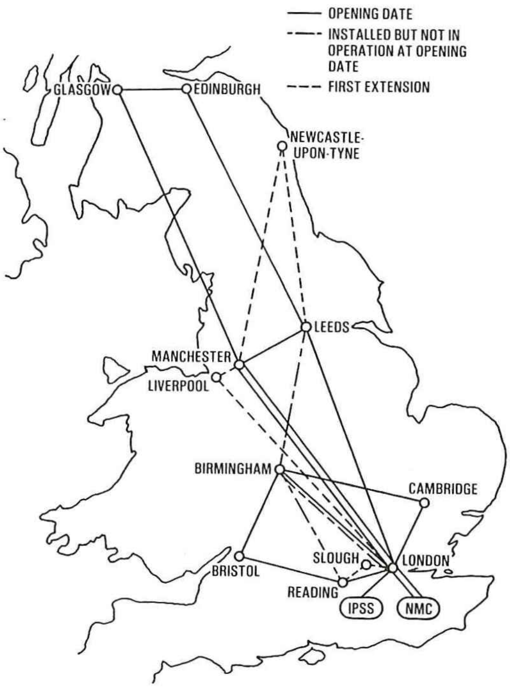

FIG. 1—UK national packet-switched network

TESTING OBJECTIVES

The primary aim of testing a system is to find any errors in its operation so that these can be corrected; without such correction, testing merely confirms the status of the system. Hitherto, BT has bought off-the-shelf packet-switched systems from commercial suppliers in this country and abroad, suitably modified to comply with CCITT* recommendations. Therefore, BT normally plays no part in the design and development of the system, and so formal acceptance testing takes place with little prior knowledge of the system. Consequently, comprehensive tests must be carried out in the limited time allowed to ensure conformity to all specifications and to verify that the system meets the complex CCITT recommendations for packet-switched systems[2] (see Table 1).

Since it is not practical to test each of the enormous number of possible combinations of events that can take place, the aims of testing have to be examined and priorities established. In this way, a meaningful set of tests can be produced. However, with software systems, undetected errors are still likely to arise after the tests have been successfully completed, even in areas of the system where testing is concentrated.

TABLE 1
CCITT Protocol Standards for Packet-Switched Networks

Recommendation	Subject Covered
X25	Packet mode terminals
X3	Packet assembler/disassembler
X28	Access for start/stop mode terminals
X29	Packet terminal/PAD interworking
X75	International interworking

PRINCIPAL TEST AREAS

The basic concern of a public administration is to offer a satisfactory service to its customers and this, together with the above considerations, leads to the following main test areas:

(*a*) *Protocols* Tests verify that the network interfaces are in accordance with the CCITT recommendations so that customer data terminal equipments (DTEs) from a number of manufacturers can operate on the network and the network can interwork with other packet networks.

(*b*) *Performance* Tests verify that the network can handle the throughput specified and that the system reacts

* CCITT—International Telegraph and Telephone Consultative Committee

† Systems Evolution and Standards Department, British Telecom Major Systems

reasonably under overload conditions; for example, congestion control.

(*c*) *Reliability* Tests verify that the network as a whole, and its component parts, meet the specified failure rates for both software and hardware.

(*d*) *Routeing* Tests verify that packets reach the destination terminal by the most efficient path without loss, duplication or corruption, and that the network is tolerant of link failures.

(*e*) *Security* Tests verify that the system is immune to illicit or accidental changes to data structures (for example, billing information) or software.

(*f*) *Billing* Tests verify the accuracy and security of data acquisition for the formation of customers' bills.

(*g*) *Network Control* Tests verify that the network can be controlled efficiently; this includes the introduction of new customers, maintenance of the network database, monitoring of the network, and diagnostics.

HIERARCHICAL APPROACH

Having established the aims of testing and accepted that complete testing is not feasible, BT has devised a practical approach to the validation of the packet-switched network. This approach recognises that the time allowed for testing is limited and that the main test areas have many interdependencies.

A bottom-up approach is advocated, where each level is verified before going on to test the higher levels. The hardware is first tested, followed by the physical and electrical interfaces. The lower level of the protocol is then tested (for example, CCITT Recommendation X25 level 2), followed by Recommendation X25 level 3. The same bottom-up technique is adopted for Recommendations X3, X28 and X29.

After the protocols have been tested, the bottom-up approach breaks down slightly as there are several parallel functions. Here, the priority allocated to each area dictates the order of the testing and the amount of effort to be expended on each test.

Errors can be found at any time, in which case testing may have to be suspended while the error is corrected. The consequences of a correction in a complex software system are difficult to predict as further errors could be introduced. In addition, the current series of tests may become invalid. Extensive retesting is then necessary, which incurs penalties in time and manpower. Even with well structured systems, it is wise to return to the lowest level of tests when corrections have been made to the system. This leads to the conclusion that the testing methods should be rapid and simple to execute, without their effectiveness being compromised.

TEST TOOL REQUIREMENTS

Manual methods of testing are not sufficient and some form of automated test tool is necessary. The requirements for such a tool are examined below.

Independence

One of the primary reasons for testing is to ascertain the acceptability of the network to customers. This necessitates the investigation of the network from the user's point of view. The interfaces the test tool has with the network should be the same as those offered to users or other external systems; for example, gateways. The tests are concerned with what the system actually does, rather than with how it does it.

Methods of testing that use equipment similar to that under test (for example, back-to-back testing) often bypass the external interface because interconnection is made through some internal means. This method is suitable for debugging individual subsystems, but may not give a correct impression of the way the total system performs. In addition, if the same software modules and hardware interfaces are used in both the testing and tested systems, they can mask each other's idiosyncracies. Therefore the test tool should not only test the system via the user interface, but should also be configured with independent hardware and software.

Repetition of Tests

When a correction is made to a system, some retesting is necessary. Therefore, a tool is required with which the suite of test programs can be easily rerun and where individual tests can be repeated in isolation.

Speed and Capacity

The test tool must also be able to retest quickly so that new versions of the system can be rapidly assessed. Furthermore, the test tool should have the ability to subject the system to sustained peak load.

Versatility

As well as load testing, the test tool should be capable of testing each aspect of the protocols and exception conditions.

Ease of Use

Although predominantly required for acceptance testing, such a test tool will be used as a maintenance aid during the life of the system, and so the skill required to operate it should be kept to a minimum to reduce training commitment. Also it must be possible to modify and add new tests with relative ease as enhancements are added to the system, or particular aspects of the system are singled out for special investigation.

Transportability

It should be possible to transport the tester to the manufacturer's premises, so that close liaison can be maintained with the system developers.

TEST TOOL IMPLEMENTATION

Once the requirements had been identified, it was necessary to find a way of implementing them within the tight timescales and with the rather limited resources available. Fortunately, some similar work concerning testing of EPSS had been carried out within BT[3]. Indeed, the approach to functional testing was similar in that a pre-defined series of stimuli was applied to the network under test, and the responses compared with those anticipated.

The design for the PSS tester, termed *AUTOFLOOD*, arose from the concepts embodied in the EPSS version and the requirements above. Considerable expertise and some BT software existed for the Ferranti Argus 700 minicomputers, and so AUTOFLOOD was based on a newer version of the same machine.

AUTOFLOOD was built into 2 half-height racks to ease transportation; these could be used as desk pedestals (see Fig. 2).

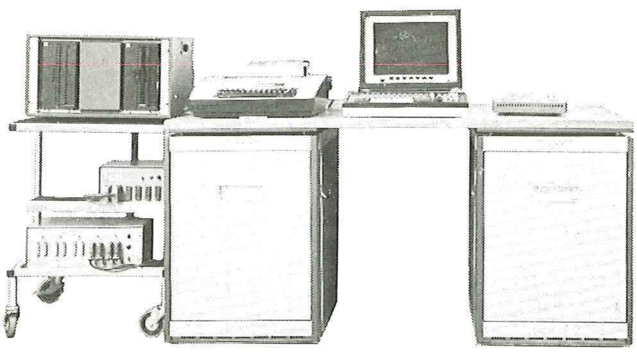

FIG. 2—AUTOFLOOD tester

A test language was devised by which AUTOFLOOD would be controlled, based on the parlance in CCITT Recommendation X25, Geneva 1978 (the most up-to-date document at the time).

TEST TOOL FACILITIES AND FEATURES

A form of compiler has been written, which operates on a source file containing commands written in the test language, and generates intermediate data structures and files. These files are used by another part of the AUTOFLOOD software (the test sequencer) to execute the specified commands, typically sending out packets and character strings, and comparing those received from the network under test with those specified in the source (test) file (Fig. 3). If the tester finds the network response differs from that specified, it immediately stops that stream of the test, prints out the observed and expected responses, and indicates at what point in the test the failure occurred. These can then be studied to determine whether the network response was incorrect, or whether the test had been written so as to expect the wrong response.

The hardware and software of AUTOFLOOD are suitable for a very wide range of requirements. AUTOFLOOD has 8 high-level data link control (HDLC) ports and up to 8 asynchronous test ports, enabling simultaneous testing of network ports of widely varying characteristics. For example, one tester port might be connected to a network port with incoming calls barred, another to one with outgoing calls barred, another might have reverse charging inhibited, some could be in a closed user group, another might be allowed to make fast-select calls, while another might not. This enables the tester to check the correct functioning of all these different network options[4].

The asynchronous capability enables the PAD to be tested and checks its interaction with the packet side of the network. This is one of the unique features of AUTOFLOOD since, to the network, it can look like a separate host and terminal.

As the throughput of AUTOFLOOD approaches 400 frames/s, it has also been very useful in performing stress tests on the network; at present, it appears to be a very effective way of performing a check on the hardware of the existing BT network nodes, and has had considerable use in screening new hardware modules before they are placed in the network.

AUTOFLOOD features some very useful monitoring facilities. Keyboard commands enable the tester to display, on a fast visual-display unit (VDU) screen, a mimic diagram of the tester showing exactly how many packets per second are flowing in and out (see Fig. 4). This assists when carrying out traffic and soak tests, since it shows immediately if there is a port causing trouble. Details of an individual port can also be presented, giving more information than the throughput display. Similarly, details of a particular logical call can be displayed.

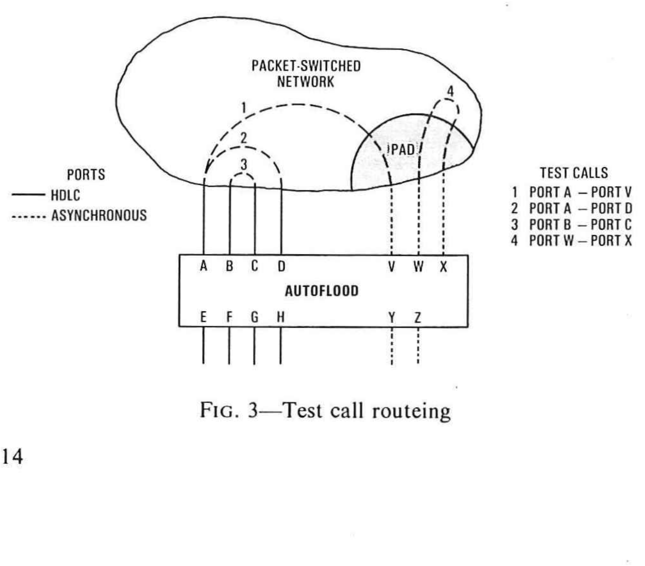

FIG. 3—Test call routeing

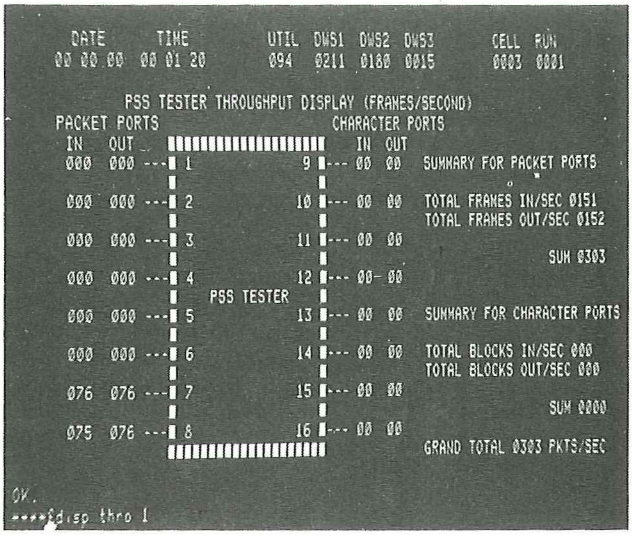

FIG. 4—AUTOFLOOD screen display

A keyboard command to instruct the tester to time-stamp data packets enables the time taken for packets to cross the network to be measured. Although this includes the time taken for low-level queuing and transmission, the figures obtained are very similar to those a customer on the network observes; thus, AUTOFLOOD has been used on several occasions to provide intending users of PSS with information to help them decide on the right balance of packet length and window size for their particular application. Separate fields at the top of the screen are continuously updated with information concerning the processor utilisation of the tester, the current number of free buffers, time, date and the current position in a test. In this way, the user can always see whether the test is progressing satisfactorily.

The tester has twin floppy discs and a reasonably sophisticated file handling system; hence, it is much the same as any other minicomputer to operate and is easy for semi-skilled personnel to use. The test files can be entered directly onto the disc by using the VDU or console terminal, and can be edited on the tester. Alternatively, they can be prepared on another computer, and then down-line loaded.

The language used to control the tester can be somewhat compact if full use is made of the abbreviations and macro expansion facilities available. For this reason, an interpreter has been provided; this takes the compiled test and prints out a much more verbose version, which is rather more like English than the test language. This has been found helpful when a particular portion of a test is being studied; for example, parts that someone else has written. In practice, the interpreter is infrequently used because, although the test language looks a little cryptic at first sight, anyone familiar with packet switching very quickly becomes adept at reading tests directly.

ADDITIONAL TEST FACILITIES

The tester can also be used for tests in a number of areas that do not involve protocol testing; for example, billing. When an AUTOFLOOD test is run, the numbers of calls set up and data packets sent are always known exactly. This precision enables the integrity of the accounting of various different types of call to be checked, by comparing the billing information generated by the network with that expected from examination of the AUTOFLOOD test. AUTOFLOOD is also useful for testing some of the NMC facilities, such as controlling, testing, and monitoring lines, to establish confidence that the NMC has done what is expected.

Congestion control is tested using AUTOFLOOD by writing tests that are deliberately designed to try to fill all the network buffers. This is achieved by forcing the network to hold data for a number of calls for a DTE (in this case AUTOFLOOD) that claims not to be ready to receive data, and then allowing in all the data to ensure that none has been lost.

FAULT DETECTION

When systems are tested, it is inevitable that conditions will be detected where there is initial doubt as to whether the system under test is at fault, whether the problem lies with the test itself or, indeed, whether a fault exists at all. Initially, despite exhaustive checks, bugs will exist in a new suite of test tables. If the fault is in the tests, the tables are easily modified and a reliable suite of test programs soon emerges. If it is found that the network is at fault, a fault report is generated and sent to the contractor's system support organisation. There are then a number of possible ways to proceed. Testing could stop until the fault is corrected, or testing could continue on an independent aspect of the system. Alternatively, the individual test that failed could be skipped and testing continued on the same aspect. Although it is recognised that further testing may be rendered invalid by a correction to the original fault, the latter alternative is often adopted so that more information surrounding the fault can be found. In addition, further faults may be found which can be corrected at the same time as the original fault. This option tends to reduce the number of software releases needed to establish a fault-free system.

With an automated test tool, the correction of a fault takes significantly longer than its detection. The correction of one fault may reveal others that had been masked by the first, and so corrected versions of the software must be subjected to the whole test suite. With AUTOFLOOD, the test suite for Recommendation X25 takes only 30 min to run, and so the software can be rapidly assessed. The results can then be fed back quickly to the programmer for any further corrections that may be necessary. The tester can easily become an effective debugging tool with the danger that, because of its rapid response, a trial-and-error approach may be taken by the implementers, and ill-conceived corrections tried.

As faults are corrected, the verifying tests are incorporated into the standard test suite to form a valuable check so that a fault that has been cleared does not reappear in later versions of the software—a problem familiar to many system developers. In this way, a library of tests can be built by which any new software release can be judged. The testing phase of the fault-clearing cycle is reduced and the major portion of the cycle is the time taken to make the software change, and to build and release new systems.

EXPERIENCE WITH PSS

Most of BT's experience of testing packet-switched networks, using the approach described, has been with the UK PSS. The contract for this network was placed with Plessey Controls Ltd. in 1978, which subcontracted the design and development to GTE Telenet in the USA.

It was felt that the acceptance testing of the system software should take place at the contractor's premises, so as to reduce the fault clearing time. The contractor provided a test configuration consisting of 3 packet switches and a single NMC, and suitable port profiles for the test network were agreed.

Prior to the arrival of the tester in the USA, a number of BT modems were shipped and commissioned so that the compatibility of the equipment could be assessed. The modems were dispensed with after it was established that the equipment was compatible.

The test team had to overcome the contractor's reservations about AUTOFLOOD, which were understandable because, in some cases, the software for the tester was newer than the software under test. To compound this situation, there was an initial period when many of the tests produced discrepancies. The problems arose partly because some invalid assumptions were made by the writers of the test tables (who were fairly new to Recommendation X25), but mostly because of the presence of some ambiguities in the X25 recommendations available at the time. The problems were dealt with in one of 4 ways:

(*a*) a network fault report was raised;
(*b*) a test-table fault was identified and the test modified;
(*c*) a specification interpretation problem was identified, which was then discussed at contractual level; or
(*d*) a fault was identified in the tester software.

It was sometimes necessary to use a passive line monitor on the test circuit to arbitrate between the tester and the network, but, fortunately, the discrepancy was very rarely found to be due to the AUTOFLOOD software.

After a time, the test suite stabilised and the tester was accepted as a reliable tool by the contractors; indeed, it was frequently used to aid debugging. Eventually, the software was considered sufficiently satisfactory to transfer testing to the UK, so that those parts of the system that could not be tested on the contractor's test environment could be checked on the large widely-dispersed network.

The approach to network tests was firstly to repeat the factory tests on the UK switches, and then to perform tests that involved the whole network. A temporary network of data links to packet switches remote from London was established. As all of the special links terminated on the packet tester, this enabled calls to be generated at any of the switches and received at any other switch. In effect, the tester became a DTE on every switch. In this way, routeing, reconnection, loading, billing and failure tests were performed on the whole network, although the maintenance of the temporary network and the co-ordination of the activities at the remote sites did present problems. In addition, a considerable number of hardware problems were experienced with the main network, which disrupted the system tests.

It was recognised that no testing can be exhaustive and that faults will always be found under normal service operation; hence, it was envisaged that part of the acceptance testing should involve selected customers using the network. However, because of the earlier delays, customers were already using the trial national network to verify their own DTE implementations. This caused additional problems during the testing phase as breaks in service had to be limited. Occasionally, the random traffic from customers had to be stopped so that tests could be performed where the exact traffic profile had to be known; for example, billing and statistics. The customers' traffic did throw up some faults, but the number was limited.

The operational network is expanding rapidly and the customers' traffic is increasing. This combination of circumstances might be expected to lead to the discovery of more system errors, but, in practice, the occurrence rate has been very small. The role of testing continues as new software, containing enhancements and corrections to old faults, is released. Subjecting new releases to the test suite on a captive test network has been effective in minimising the problems encountered in using new software operationally.

EXPERIENCE WITH OTHER NETWORKS

Similar test techniques have also been used on other networks, although not as extensively as with PSS. Before being shipped to the USA, the tester was used with the Euronet packet-switched network, in which it was able to isolate some suspected faults. More recently, the techniques have been applied by BT's IPSS to test the compliance with

Recommendation X75 of connections to other packet networks throughout the world; for example, Spain and Japan. In addition, the PSS–IPSS gateway and gateways to other services, such as Telex were tested. In each case, the same basic approach has been used, but the test tables have normally undergone some modifications.

FUTURE DEVELOPMENTS

Currently, BT has 3 AUTOFLOOD testers, which are used for testing PSS, IPSS and other packet-related projects. In addition, other organisations have purchased AUTOFLOOD testers. Further potential users have expressed interest in the next generation microprocessor-based tester system, which is currently at an advanced stage of development. This will offer portability, wider capability and cost reduction.

CONCLUSIONS

The techniques used by BT to test packet-switched networks do not form a strict methodology, but rather an approach that experience has proved to be effective. This would not be possible without a test tool such as AUTOFLOOD.

With the advances in specification and design languages, and structured development techniques, the number of errors remaining at system integration time should be small; nevertheless, some will exist and so good system test techniques will be necessary for some time to come.

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2 CCITT Recommendations X25, X75, X3, X28 and X29.

3 NORTON, M. J. Experience in Software Test Techniques for Packet-Switching Exchanges. Proceedings of the Third International Conference on Software Engineering for Telecommunications Switching Systems.

4 MILLER, C. G., and NORTON, M. J. Autoflood—A Flexible Test System for Packet-Switched Networks. NATO Advanced Study Institute on Advances in Distributed Computing, 1980.

Book Reviews

Computer Aided Design of Microwave Circuits. K. C. Gupta, Ramesh Garg, and Rakesh Chadha. Artech House Inc. 656pp. 158 ills. £33·00.

The authors, who come from the Indian Institute of Technology, have undertaken here, for the first time, the task of incorporating into a one volume work the multifarious aspects of the computer-aided design (CAD) of microwave-circuits. Sections have been devoted to modelling of circuit elements, to analysis, and to optimisation and CAD programs.

Modelling of transmission structures and discontinuities in metallic waveguides, coaxial- and strip-lines, and microstrip is comprehensively covered, including coupled lines, but the newer dielectric waveguides and finline now coming into use receive only passing mention. A chapter on lumped elements contains one of the few references to practical results, but the descrepancy from theory does not aid the thesis. After a highly mathematical analysis of 2-dimensional components, the modelling of semiconductor devices is despatched far too briefly. Measurement techniques, including automatic network-analyser error correction and the modern 6-port technique, are covered extensively. However, practical details such as dynamic-range problems in transistor measurements and the sliding-load technique of calibration are omitted, and the powerful signal-flow-graph technique could have been more fully explained.

Five chapters on analysis cover well the principles and mathematics, including sparse-matrix techniques. The handling of series and shunt feedback in chain-matrix analysis is explained, but the testing of the Brune conditions to ensure validity in each case is not. Sensitivity analysis and tolerancing are covered, and a chapter is devoted to time-domain analysis.

The basic concepts of optimisation, including objective-function formulation, constraints, transformations, weightings, local versus global minima etc., are explained with exceptional clarity; only constraining interrelations between variables are glossed over. Two chapters describe thoroughly all the major direct-search and gradient techniques of optimisation, but it is a pity that no short section is given over to a consideration of their relative merits or an identification of where each is most useful; nevertheless, their bringing together is commendable.

Finally, a few typical computer programs are described, from the authors' own *MCAP* to some that are commercially available from Compact Engineering Inc., Palo Alto, USA.

This excellent book has evolved from material used in the teaching of a graduate course, and full comprehension of it requires university-level mathematics. But this should not deter those readers who are less experienced, as they will still learn much from the book. The authors' style throughout is commendably clear and easy to follow; they commence each chapter with a concise overview and conclude it with a useful bibliography. One suspects that the authors have never used CAD in anger; yet the lack of practicality detracts little from a work which will fill a significant gap on every practicing microwave-engineer's bookshelf, both as a guide to techniques and as a source of reference material.

M. PILGRIM

Engineering Science, Vol. 2. D. Titherington, and J. G. Rimmer. McGraw-Hill Ltd. ix+184pp. 120 ills. £4·25.

This paperback has been written primarily to meet the requirements of the Technician Education Council's (TEC's) standard unit Engineering Science III, but additional material on pressure measurement and the basic theory of flow-rate measurement has also been included.

Twelve chapters cover work, power and energy; momentum; torque and angular motion; gases; energy in thermal systems; pressure and its measurement; temperature and its measurement; fluid flow and its measurement; testing of materials; capacitive and inductive circuits; block diagrams (of systems); and logic systems. Each chapter contains worked examples, and concludes with a number of problems for the student to attempt, with numerical answers given where appropriate.

Unlike so many other books written for TEC courses, the authors have not quoted the learning objectives from the syllabus at the beginning of each chapter; indeed the syllabus itself is not given in the book.

The book is liberally illustrated with clearly annotated diagrams and the writing style is easy to read and understand; it should prove to be a useful basic textbook.

R. HARVEY

A New Earth Station at Goonhilly Downs for a Satellite Service to Ships
Part 2—The Access Control and Signalling Equipment

M. FLACK, C.ENG., M.I.E.R.E., and T. J. KENT, BSC.†

UDC 621.396.676 : 621.396.946

This 2-part article describes briefly how the INMARSAT satellite service to ships functions and gives details of the equipment provided at the earth station at Goonhilly Downs. Part 1 of the article described the design of the antenna and radio equipment. This second part describes the access control and signalling equipment.

INTRODUCTION

The first part of this article[4] outlined briefly the operation of the International Maritime Satellite Organisation (INMARSAT) system and described the antenna and radio equipment provided at the UK's coast earth station (CES) at Goonhilly Downs. This concluding part describes the associated access control and signalling equipment (ACSE) at the CES and details the call set-up procedures.

The ACSE accepts calls from ships and from the public and leased telephone and Telex networks, modulates and demodulates the radio-frequency (RF) carriers, and carries out all the switching and signalling functions necessary to enable calls to pass through the INMARSAT system and be dealt with by the inland network, or the ships terminal equipment as appropriate. It also records all stages of the calls to provide the raw data for billing and statistical purposes.

The INMARSAT system, like its forerunner the MARISAT system[5], requires that the transmission channels are allocated on a demand basis in order to minimise the number of satellite channels required (because of satellite power limitations), and that the ship earth station (SES) costs should be kept to a minimum to encourage ship owners to fit terminals in their ships. These 2 requirements lead to considerable complexity in the design of the ACSE at the CES. This complexity is further increased by the need to operate in conjuction with a network co-ordinating station (NCS) provided by INMARSAT, which enables several CESs to operate in the system and share the available channels. As part of its control and co-ordinating function, the NCS receives all time-division multiplexed (TDM) channels transmitted by the CESs in its region, and retransmits the appropriate assignment and signalling information on the *common* TDM channel to which all CESs and ships, except those engaged in Telex calls, are tuned.

† Satellite Systems Department, British Telecom International

Summary of Abbreviations used in this Article

ACSE	Access control and signalling equipment
BCH	Bose Chaudhuri and Hocquenghem
CES	Coast earth station
CPU	Central processing unit
DBE	Digital baseband equipment
DTMF	Dual-tone multi-frequency
DTR	DTMF receiver
EFWS	Electronic 4-wire switch
FIFO	First-in-first-out
LCS	Line control subsystem
LIC	Line interface card
LOGOS	Programming language used for LCS and EFWS
NCS	Network co-ordination station
MTG	Multi-tone generator
PSK	Phase-shift keying
PTS	Proceed-to-select
RAM	Random-access memory
SCOP	System control and operating position
SCP	System control processor
SES	Ship earth station
SF	Single frequency
TDM	Time-division multiplexed
TDMA	Time-division multiple access
VDU	Visual display unit

FUNCTIONS OF THE ACSE

The ACSE at Goonhilly Downs CES is a complex computer-controlled system having considerable processing power in 3 of its main subsystems. The main functions of the ACSE are detailed below.

(*a*) Communicating with ships and the NCS via the request and signalling channels to establish the type of service required by the originating subscriber.

(*b*) Initiating, or providing the correct responses to in-band signalling over satellite and terrestrial paths.

(*c*) Checking the validity of ships' requests against a database, which may be readily updated.

(*d*) Recording of data which can be subsequently used for

(*i*) management statistics and billing for ship-originated calls,

(*ii*) cross-referencing against operators' dockets for shore-to-ship calls originated in the UK,

(*iii*) international accounting (for transit calls),

(*iv*) space segment accounting and statistics for use by INMARSAT, and

(*v*) maintenance purposes.

(*e*) Switching of audio circuits to and from terrestrial circuits and the frequency-modulated (FM) channel units. Terrestrial circuits include those to the British Telecom (BT) international switching centre (ISC) at Mondial House, leased circuits and the dedicated circuits to the Maritime Rescue and Co-ordination Centre (MRCC) at Falmouth.

(*f*) Switching of Telex circuits to and from terrestrial circuits and the appropriate TDM and time-division multiple access (TDMA) timeslots. Terrestrial Telex circuits include those to the gateway exchange (Keybridge), leased circuits and dedicated MRCC circuits.

(*g*) Tuning of a given FM channel unit to the correct transmit and receive frequency pair of the 299 available as instructed by the NCS, for a given voice call.

(*h*) Allocating TDM/TDMA timeslots as required for a Telex call and informing the ship via the NCS.
(*i*) Providing both voice and Telex order wires for inter-CES use.

The ACSE has maintenance and test facilities which include: a dedicated maintenance system that can also simulate an NCS, in-built software diagnostic routines, a keyboard for operator interaction with the ACSE, a printout of statistical tables, the setting up of test calls, and test access and test jack frames together with associated test desks. It also includes facilities for switching in stand-by units on detection of a failed unit, up-dating a display on a mimic panel, sounding a suitable alarm and printing details of the failure on a dedicated printer.

COMPONENT PARTS OF THE ACSE

The ACSE is best considered as a number of subsystems interconnected as shown in Fig. 11. These subsystems are:

(*a*) system control processor (SCP),
(*b*) line control subsystem (LCS),
(*c*) electronic 4-wire switch (EFWS),
(*d*) digital baseband equipment (DBE),
(*e*) FM equipment,
(*f*) intermediate frequency (IF) subsystem,
(*g*) system control and operating position (SCOP) and mimic panel,
(*h*) test ship terminal,
(*i*) maintenance system and NCS similator,
(*j*) Telex and voice order wires, and
(*k*) test desks and jackfields.

The SCP, LCS and EFWS each have their own individual processing facilities. Each interacts closely with the others and with the remainder of the ACSE subsystems, and so it was essential, from the outset, to design into the system a way of passing data between them. The system devised encases the data within a message which names both the recipient and the originator and, once put on the data highway, is directed to the correct processor. Fig. 12, which is a simplified block diagram of the ACSE hierarchy, shows the data paths within the system. A virtual data path exists for the control of the EFWS by the SCP although, in practice, the data flows via the LCS.

To aid understanding of this system, the functions of each subsystem are described briefly below followed by examples of voice and Telex call set-up showing how the subsystems interact with one another and with the NCS.

System Control Processor

Two SCPs are provided, main and stand-by. Each SCP comprises a proprietary minicomputer, 2 tape drives and a 12·5 Mbyte Winchester disc. The data path between the on-line SCP and the SCOP uses a standard data interface (RS-232-C) and switch, while connection with the rest of the system is via the LCS.

The software required by the SCP for processing of calls is normally held on the Winchester disc together with data tables (for example, lists of ships authorised to use the system etc.) and billing data. Each processor is equipped with 256 Kbytes of random-access memory (RAM), some of which is used in conjuction with the disc to form a real-time disc operating system. The remainder is occupied by the applications program, call registers, data tables and, at any instant, by the software module which the SCP requires for carrying out a particular function. During the operation of the ACSE, the disc operating system continually brings different software modules from the disc into the processor memory.

A sequential block of the SCP's RAM used for recording the parameters of a particular call and known as a *call register*, is allocated at the start of each call. Call registers are dynamically assigned from a part of processor RAM set aside for this purpose. There is memory available for about 100 call registers, which is sufficient to serve the ultimate call capacity of the ACSE.

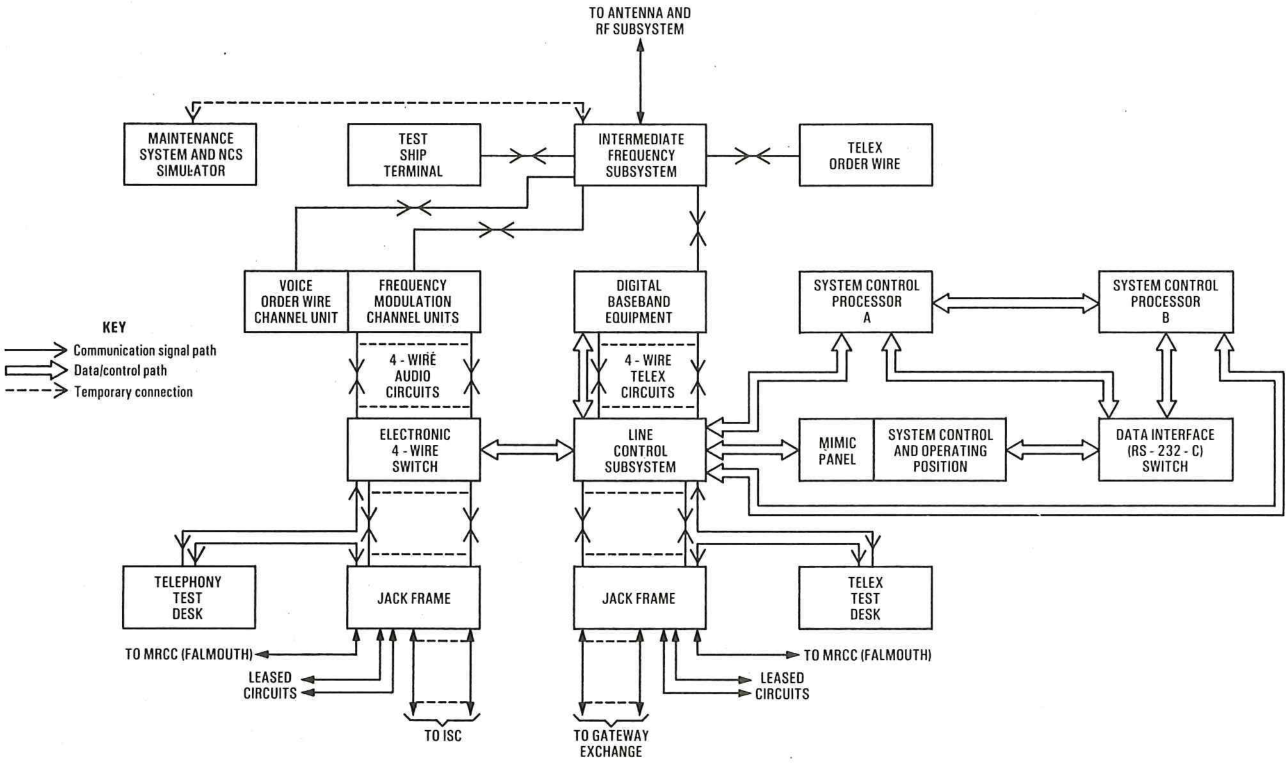


FIG. 11—Block diagram of the access control and signalling equipment (ACSE)

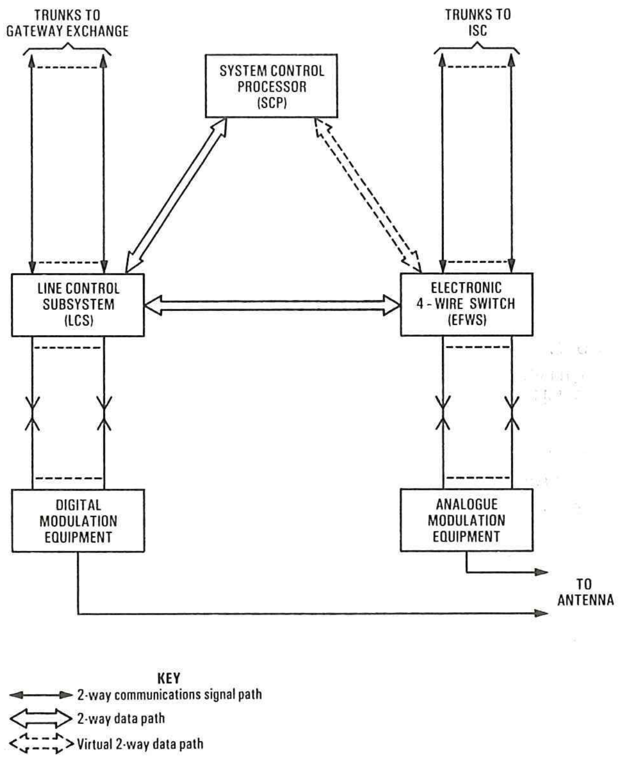


FIG. 12—Simplified block diagram of the ACSE

The parameters recorded during a call's progress include the various items of equipment used, the ship's identity, the destination number and the times for billing and accounting purposes. All the call register parameters are passed to the stand-by SCP so that it is ready to take over in the event of failure of the on-line SCP. Both SCPs log copies of the call registers to their respective discs and, except for SCP failures, the 2 discs have identical files. From these archive tapes, a subset of the information is recorded off-line by the maintenance system onto the transfer tape, which is sent to BT's Data Processing Executive (DPE) for billing, accounting and statistical purposes.

From the contents of the call register, the SCP is able to monitor the progress of any call, and this is the only part of the ACSE that can identify a call as a single entity. The other subsystems of the ACSE have, for example, sufficient resident software to initiate or respond to the various signalling protocols, but treat the satellite and terrestrial parts of the same call as if they were separate. It is the overall control exercised by the SCP that enables a complete call to be set up.

The main functions of the SCP are:

(*a*) loading of the SCP program from tape or disc,
(*b*) loading of the processors in the LCS and EFWS,
(*c*) controlling call set-up and clearing,
(*d*) providing an interface with the maintenance staff via the SCOP,
(*e*) logging of parameters of each call,
(*f*) validating call attempts against an authorised ship list,
(*g*) maintaining of a list of ships busy via the CES,
(*h*) interpreting *request* messages from ships (including decoding of the Bose Chaudhuri-Hocquenghem (BCH) error-checking code)
(*i*) interpreting messages on the signalling (common TDM) channel from the NCS and responding as necessary,
(*j*) formulating signalling messages for transmission to the NCS on the CES's own TDM channel for repeating to ships on the common TDM channel,
(*k*) checking international telephony country codes against a list of allowed codes (this is not necessary for Telex calls for which the gateway exchange checks the codes), and
(*l*) translating abbreviated dialling (2-digit) codes into the correct selection sequence.

Line Control Subsystem

The LCS performs control and monitoring functions for the whole of the ACSE and switching functions for Telex calls through the CES. It is the sole link between the SCP and the remainder of the ACSE (except the SCOP which interfaces directly with the SCP). Interconnections between the LCS and the rest of the system are shown in Fig. 13.

A proprietary data communications processor, especially developed by the ACSE contractor for general use in digital communications systems switching and control applications,

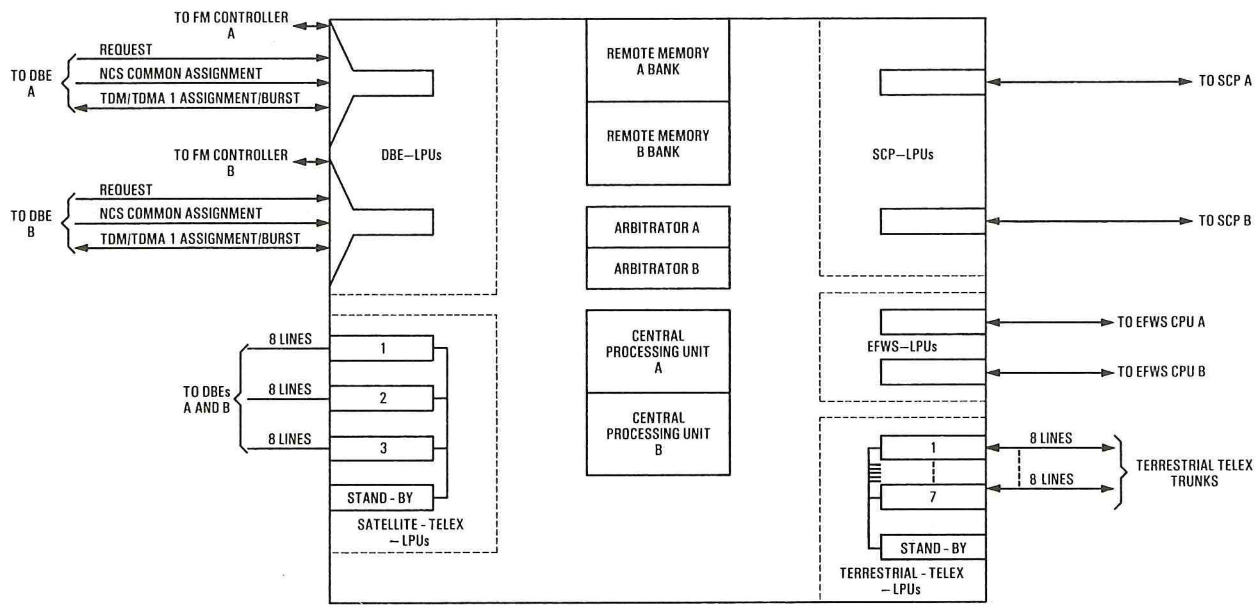


FIG. 13—Line control subsystem configuration

is used for the LCS. It is a multi-microprocessor system employing 2 central processing units (CPUs) and a number of line processing units (LPUs). The on-line CPU co-ordinates the actions of the LPUs, which interface with the outside world.

Redundancy is provided internally, with the CPUs arranged in a one stand-by for one main group, and the 19 LPUs in groupings between one stand-by for one main unit and one stand-by for 7 main units, according to the effect on traffic of a failure in the group. The LCS also includes an arbitrator that monitors the functioning of the LCS and controls the switching between the on-line and the stand-by CPU. The on-line CPU controls the redundancy switching of the LPUs.

The CPUs and LPUs use the Mostek type 6502 microprocessor. Each has exclusive access to some associated local memory, the CPUs having 16 Kbytes and the LPUs having 32 Kbytes of such memory. Each CPU also has associated with it an individual bank of remote memory comprising 128 Kbytes of RAM to which the on-line CPU and LPUs all have access.

The remote memory stores data that is common to both the LPUs and the CPUs and also provides post-boxes for the passing of data between any 2 units of the LCS. For example, a Telex circuit between a ship and a terrestrial terminal would use 2 post-boxes, one for each direction of traffic, to link the LPUs which interface with the terrestrial and satellite transmission paths. The post-boxes are areas of memory arranged under the control of the CPU to act as first-in-first-out (FIFO) buffers.

Software functions that are specific to an individual LPU or CPU are stored in the local memory since access to it is immediate, whereas access to the remote memory may be delayed under certain circumstances by the need to queue.

To facilitate the use of this communications processor, the contractor has developed a high-level language known as *LOGOS*, and an executive program which provides a number of software aids such as timers and diagnostic facilities that enable software to be developed without the need to program, for each application, routines which are commonly required.

An LPU is designated by reference to the device to which it interfaces; for example, the LPU connected to the DBE is referred to as the *DBE–LPU*. There are 5 types of LPU: the DBE–LPU, the EFWS–LPU, the SCP–LPU, the satellite-Telex–LPU and the terrestrial-Telex–LPU. Each type is programmed specifically for its application and fitted with a card (where card refers to a printed-wiring board equipped with components) to provide the correct electrical interface. The satellite- and terrestrial-Telex–LPUs are programmed to respond to the signalling over the satellite and terrestrial paths respectively. The EFWS and SCP–LPUs are programmed to support data communication between the subsystem to which they are connected and the LCS. They are also responsible for detecting failure of data communication (by the absence of messages) and initiating switching to stand-by equipment. Perhaps the most complex LPU is the DBE–LPU, which sends signalling-channel information to the DBE, receives signalling-channel information from the DBE (from the NCS), receives *request* messages from the DBE (from ships), and interchanges control and status information with the FM controllers. Two FM controllers, main and stand-by, are associated with a group of up to 16 FM channel units. Their function is to direct control information to and collect status information from the interface module of each channel unit. The DBE–LPU also has to detect any errors in the data paths associated with it and initiate switching to stand-by equipment.

Electronic 4-Wire Switch

The EFWS performs signalling and switching for audio circuits under the control of the SCP, interfacing the satellite transmission and signalling with that of the terrestrial network, and providing access for test purposes to and from the telephony test desk. It is shown diagrammatically in Fig. 14, and comprises the following hardware modules:

(*a*) 2 CPUs, main and stand-by, each having 64 Kbytes of RAM,

(*b*) 2 digital multi-tone generators (MTGs) which produce all signalling, information and alignment tones,

(*c*) 8 R2 tone receivers for decoding the CCITT† R2 analogue signalling[6] from the ISC and subsequent exchanges in transit calls,

(*d*) 4 dual-tone multi-frequency (DTMF) tone receivers (DTRs) for decoding the signalling from the ships (CCITT Q23), and

† CCITT—International Telegraph and Telephone Consultative Committee

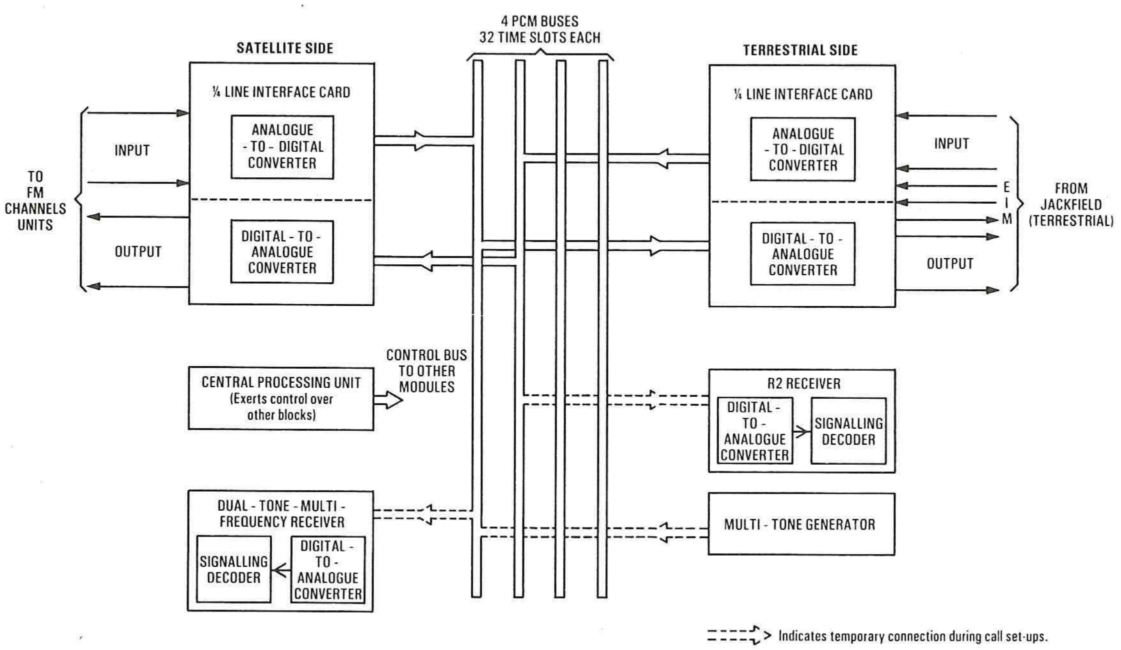


FIG. 14—Block diagram of the electronic 4-wire switch

(*e*) 11 line interface cards (LICs), each providing four 4-wire audio circuits, E- and M-lead signalling and an interrupt-control input for R2 circuits.

Audio signals entering or leaving the EFWS are in analogue form, but they are processed in a digital format within the EFWS. Each 4-wire circuit is connected to an LIC, which uses single-chip pulse-code modulation (PCM) codecs to convert between analogue and digital signals using 8-bit μ-law PCM. Each digitised audio channel has access to a time slot in one of four 8-bit-parallel 32-time-slot PCM buses operating at 2·048 Mbit/s. The time slots used for each call are allocated by the CPU. This gives the EFWS the capability of inter-connecting 128 simplex audio channels. However, as a 4-wire circuit requires one time slot in each direction, one time slot from each of 2 buses is used thus giving the EFWS the capability of interconnecting up to 64 audio circuits, although initially the ACSE has been equipped for only 13 satellite circuits.

The tone receivers for both R2 and DTMF signalling are designed to detect only analogue signals and therefore require codecs to convert between analogue and PCM signals. Signal decoding is achieved by using chip sets specifically designed for signalling purposes. Each LIC can be used for any type of audio circuit (that is, satellite, terrestrial PSTN or leased line) and the function to be performed is determined by an entry in a software look-up table held in the CPU. The CPU, which has a control bus connected to all EFWS modules, has sufficient capability to perform all the necessary signalling functions via the LICs, but needs to be controlled by the SCP for setting up and clearing down calls. The interaction of the 2 subsystems is explained later under Call Set-up Procedure.

Digital Baseband Equipment

All of the transmission equipment that provides digital communication with the satellite is contained within 2 groups known as *DBE A* and *DBE B*. The 2 groups contain identical equipment and are arranged as a main and stand-by pair. Listed below are the main components that make up each DBE.

(*a*) 2 request receivers, one for each of the 2 *request* channels.

(*b*) 2 TDM transmitters to allow 2 TDM transmissions each having one signalling channel and up to 22 Telex channels. A transmitter comprises:

(*i*) a TDM modulator which turns the input digital stream from the multiplexer into a 2-phase phase-shift keying (PSK) 1·2 kbit/s signal at the appropriate IF frequency,

(*ii*) a TDM multiplexer which assembles the signalling channel and 22 Telex channels into a TDM frame, and

(*iii*) 6 Telex buffers which are shared with the TDMA multiplexer. These are FIFO buffers which take in Telex signals from the satellite-Telex–LPU and pass them to the multiplexer when required. Similarly, data from the TDMA multiplexer is taken and sent out to the satellite-Telex–LPU at a constant rate.

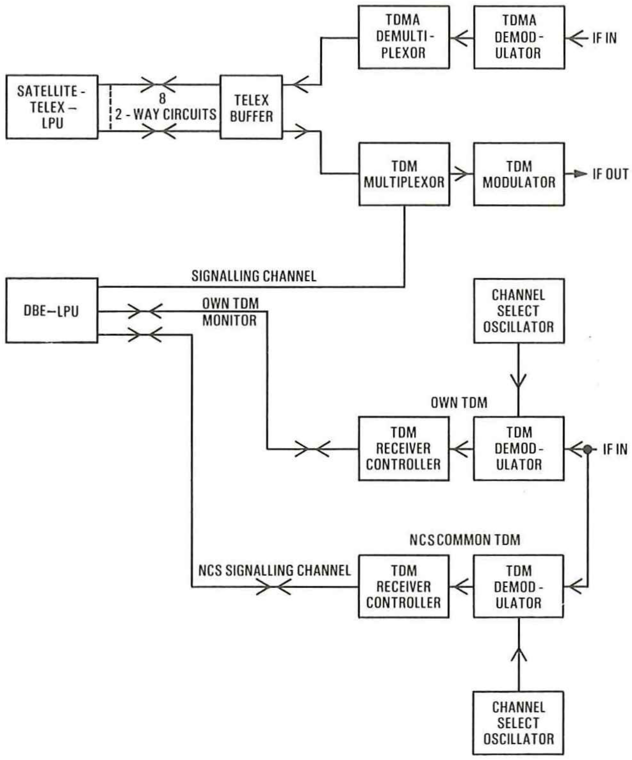
(*c*) 2 TDMA demodulators, each of which demodulates the 2-phase PSK, 4·8 kbit/s TDMA bursts from up to 22 ships.

(*d*) 2 TDMA demultiplexers to separate the 22 bursts into the appropriate Telex channels.

(*e*) 3 TDM demodulators, 1 for receiving signalling messages from the NCS and 2 for monitoring the CESs own TDM transmissions.

(*f*) 3 channel select oscillators which provide the correct frequencies to the TDM demodulators for the TDM transmissions concerned.

(*g*) 3 TDM receiver controllers which send signalling messages from the TDM demodulators when polled by the DBE–LPU.



Notes: 1 Only one own TDM transmitter and receiver shown
2 Timing and frequency units (TFUs) have been omitted for clarity since all modules receive signals from the TFUs

FIG. 15—Simplified block diagram of the digital baseband equipment

(*h*) 3 timing and frequency units which provide signals for reference and clock purposes to virtually all the DBE modules.

(*i*) An alarm panel.

(*j*) Power supplies.

(*k*) IF and baseband jackfields for monitoring purposes.

Fig. 15 is a simplified block diagram outlining the interconnections between the DBE and the LCS. It should be noted that the DBE–LPU within the LCS monitors the status of the various modules of the DBE so that a switch-over between the 2 DBEs can be accomplished in the event of a module failure.

FM Equipment

As has been described in Part 1 of this article[4], audio communication with ships uses a single-channel-per-carrier scheme using narrow-band companded FM with frequency channels allocated by the NCS on a demand assignment basis. The FM equipment provides the necessary frequency channel selection, modulation and demodulation of the audio signals, companding and carrier control.

The initial installation of FM equipment at the UK CES comprises

(*a*) 13 traffic channel units,

(*b*) a test channel unit for satellite loop tests and connected to the L-band IF equipment,

(*c*) a voice order wire channel unit to provide communication with other CESs,

(*d*) 2 FM controllers,

(*e*) timing and frequency units to provide reference signals to the synthesisers and modulators, and clock signals for the digital modules,

(*f*) 2 power supplies, diode coupled, to provide an interruption-free supply in the event of one unit failing, and

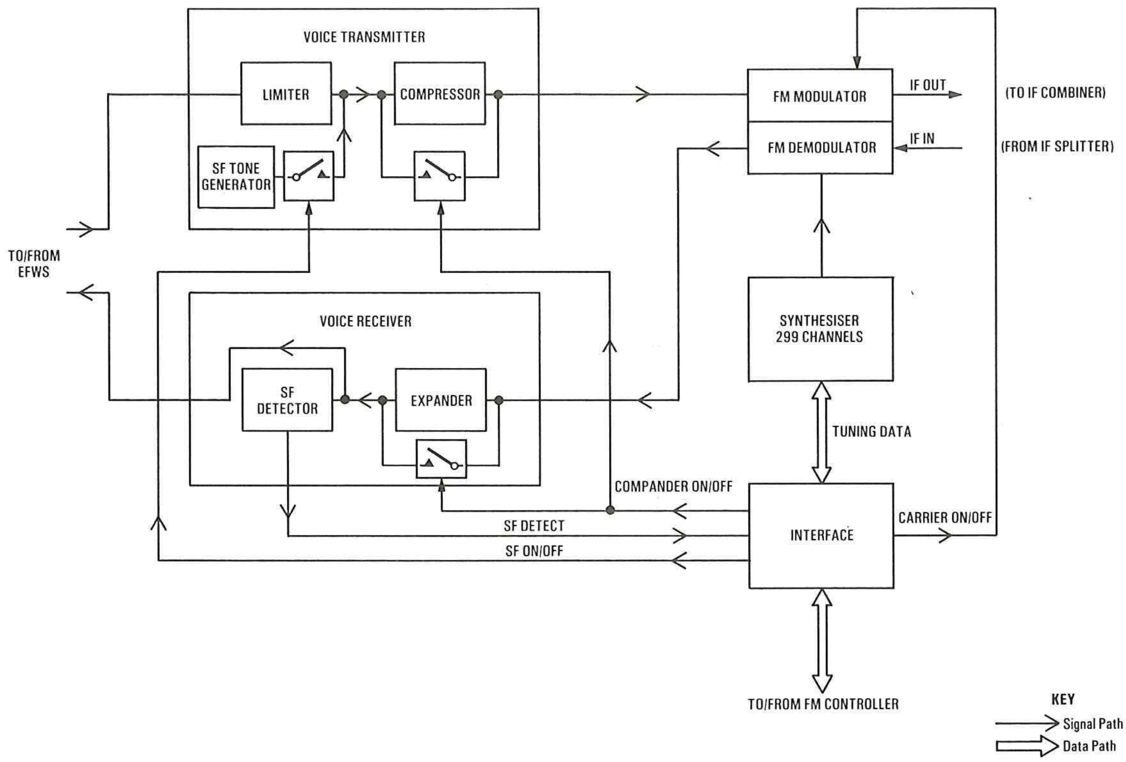


FIG. 16—Block diagram of FM channel unit

(*g*) a combiner for combining the outputs from the channel units prior to feeding the IF subsystem.

The functions of the FM equipment are carried out for each audio channel by an FM channel unit that is allocated and controlled by the SCP. Communication between the SCP and the channel unit is via the FM controller and the DBE–LPU in the LCS. A block diagram of an FM channel unit is given in Fig. 16.

The FM modem (modulator and demodulator) is driven by a synthesiser module which is capable of tuning with a high degree of accuracy to any one of the 299 channels allocated to the INMARSAT system.

The voice transmit module includes a compressor, a limiter to prevent over-deviation of the FM carrier, and a 2600 Hz single-frequency (SF) tone generator for use during the call set-up procedure. The voice receive module includes an expander and an SF tone detector. When the channel unit is used for voice calls, the compressor and the expander are included in the circuit, but these are switched out by the SCP if the circuit is required for data transmission; the signalling information sent out by a calling ship indicates the type of circuit required and the SCP acts automatically on that information. This choice is not available for calls initiated from the terrestrial network.

The interface module receives and distributes the control signals from the FM controller module and sends back status information; for example, SF tone received.

IF Subsystem

The IF subsystem provides the interface between the RF equipment located at the CES antenna site and the ACSE in the maritime equipment area. A block diagram of the IF subsystem is given in Fig. 17.

The subsystem combines and separates the RF carriers as necessary and includes translators to convert between 70 MHz, which is the IF used on the RF equipment at Goonhilly Downs, and 90 MHz, which is the IF used by the ACSE equipment. Monitoring facilities are also included in the subsystem.

TABLE 4
Grouping of ACSE Signals

C-band	L-band
FM channel units TDM/TDMA modems in DBE A and DBE B Test FM channel unit (receive) Test ship terminal	Telex order wire Voice order wire Test FM channel unit (transmit)

The active units in the subsystem are duplicated as operational and stand-by units, the change-over between them being carried out by motorised coaxial switches under the control of the LCS.

As separate L-band and C-band RF equipment is necessary at the antenna site, the IF subsystem deals separately with the signals in these 2 bands. The grouping of the ACSE signals is shown in Table 4.

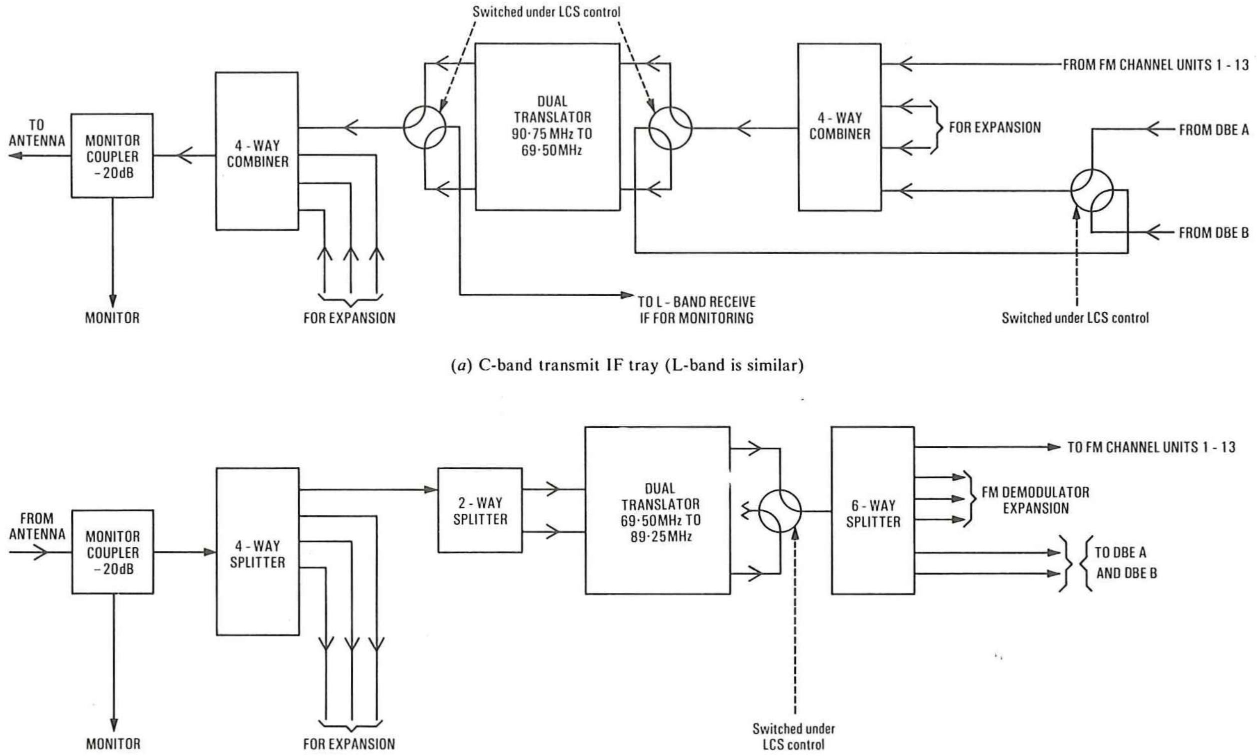
System Control and Operating Position

With a computer-controlled system, it is essential to have an explicit and lucid interface between the system and the staff who are to operate and maintain it. For the ACSE, this interface is provided by the SCOP desk (see Fig. 18), which contains the following units.

(*a*) *Visual display unit* (*VDU*) A VDU and keyboard enable direct communication with the on-line SCP. The system may be interrogated by suitable English language commands.

(*b*) *Alarm printer* In addition to an audible warning, the alarm printer gives details of the fault condition including the name and exact location of the failed module. A second alarm printer, which is located in the station operations control area, duplicates this printout.

(*c*) *Mimic panel* This shows a visual representation of the system status and shows which, if any, stand-by equipment is currently on-line. This facility takes status infor-



(*a*) C-band transmit IF tray (L-band is similar)

(*b*) C-band receive IF tray (L-band is similar)

FIG. 17—Simplified block diagram of IF subsystem

mation from switch and relay contacts within each equipment rack as well as from software.

One of the principal uses of the SCOP is the location and diagnosis of equipment failures within the ACSE.

In addition, the SCOP is also used for obtaining data on the overall performance of the system. The system is monitored continuously, and parameters on Telex and telephony circuits are recorded and used to print out statistics on the performance of the system. For hard copies of the reports, the output may be directed to a bulk printer associated with the SCP rather than, or in addition to, the VDU. (The bulk printers are separate from the alarm printers and operate at 180 characters/s, whereas the latter operate at 30 characters/s.)

The amendment and/or the updating of the system tables (for example, the authorised ship list and the list of allowed country codes for telephony) is carried out by means of the SCOP desk.

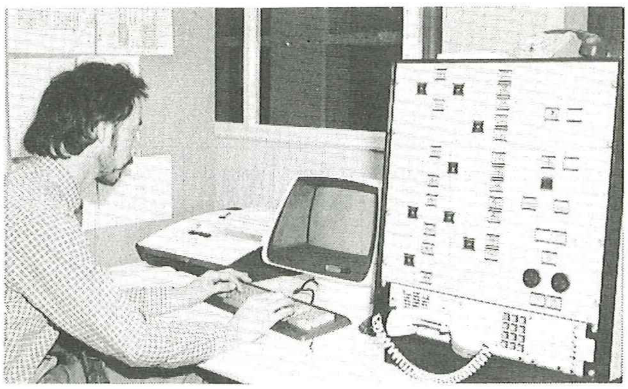


FIG. 18—System control and operating position

The SCOP is also used for the provision of voice order wire facilities, using a dedicated FM channel unit, to provide communication with other CESs. Voice frequency signalling over the order wire is provided for the selective calling of stations.

Test Ship Terminal and Telex-only Order Wire Terminal

One of the INMARSAT requirements for a CES is that it should have the same L-band transmit and receive capability as an SES. This is fulfilled in the ACSE by the test ship terminal which is a standard commercial ship terminal without the antenna, L-band transmitter and low-noise amplifier; these functions are provided by the CES antenna and RF equipment described in Part 1 of this article.

It is important to note that the test ship terminal is not under the control of the SCP. In normal use, unless special patching arrangements are made at IF, the test ship terminal can only make a call to the ACSE test desk via the satellite, employing the normal SES–CES and CES–NCS protocols. Thus, the effect is identical to a call initiated from an SES. The provision of this facility is most important as it provides a way of thoroughly testing the system in the event of apparent equipment failure. The practice at INTELSAT earth stations of using the equipment provided for traffic to make a satellite loop test is precluded in the INMARSAT system because of the L-band-to-C-band and C-band-to-L-band translations in the satellite transponders, and the demand-assigned nature of the system.

Parts of a commercial ship's terminal without voice facilities are used in a similar manner to the test ship terminal to provide Telex order wire facilities to enable the Goonhilly Downs CES to exchange service messages via the satellite with the INMARSAT operations control centre and with other earth stations in the system.

Maintenance System

The maintenance system is a self-contained minimum-hardware version of the ACSE designed for both hardware troubleshooting to component level and software updating and development. In addition, it can function as an NCS simulator and be used for making transfer tapes for billing purposes. The maintenance system comprises an SCP with 2 disc drives, LCS, EFWS, FM modems, DBE, IF equipment and jackfields. Each subsystem has at least one of each of the ACSE component parts. The Telex and telephony jackfields have trunks to the jackfields in the operational system, allowing the maintenance system to be connected to the ACSE or to the terrestrial links as required. A high-speed printer, operating at 900 lines/min, is provided for making listings of programs and system tables.

An NCS simulator is required to test the ACSE of any new CES prior to conducting commissioning tests with the INMARSAT system. This is intended to ensure that the new CES does not cause confusion to the NCS's software by sending unexpected signalling messages and causing the NCS to crash. By loading suitable software into the maintenance system SCP, tuning the maintenance system DBE TDM modulator to the common TDM frequency, and cross-connecting at IF, an NCS can be simulated without hardware or software modification to the ACSE.

An important function of the maintenance system is the production of tapes for the transfer of data from the CES to the DPE Computer Centre. Archive tapes are made, initially, once daily by dumping log files from the discs of both on-line and stand-by SCPs. On the maintenance system these are first copied on to disc files and a comparison carried out. If there are no differences between the 2 versions, this can be taken as a good indication of no corruption in the logging process, and only one tape need be kept for long-term storage. If the archive tapes differ for no apparent reason, the dumping process may be repeated, perhaps using the alternative tape drive. The transfer tape is then made by extracting only that logged data relevant to the DPE billing and accounting system (STAR).

CALL SET-UP PROCEDURE

To set-up a call via the CES requires a complex interaction in both hardware and software of the various subsystems just described. The following sections indicate the procedure for typical calls and the interaction of the various parts of the ACSE with the NCS and SES.

Ship-to-Shore Audio Call

A call in the ship-to-shore direction (see Fig. 19) is initiated by a message transmitted by the SES in a TDMA burst on one of the 2 system request channels and received by all CESs. The *request* message is initiated in the SES by the pressing of a key by the ship's operator and it has the format given in Fig. 20.

At the Goonhilly Downs CES the message is received in one of 2 on-line request receivers (one tuned to each of the 2 request channel frequencies) of the ACSE and stored in an associated FIFO memory. The 2 FIFO memories are polled alternately by the LCS and any *request* message detected is sent to the SCP via the LCS. The SCP decodes the BCH data block for errors and to see whether the message is intended for the UK CES. If so, a call register is allocated by the SCP, a serial number given to the call and both the serial number, the data and the time entered in the call register. Before the call is finally accepted, the SCP checks a table of authorised ships and rejects a call from any unlisted ship unless the *request* message priority field indicates a distress call. In the latter case, the call is allowed to proceed whether or not the calling ship is authorised to make calls via Goonhilly Downs.

When the call has been accepted by the ACSE, the

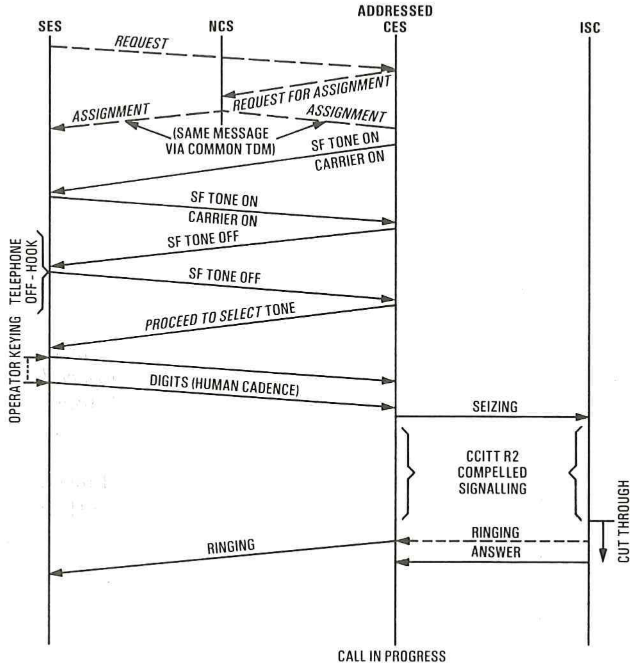
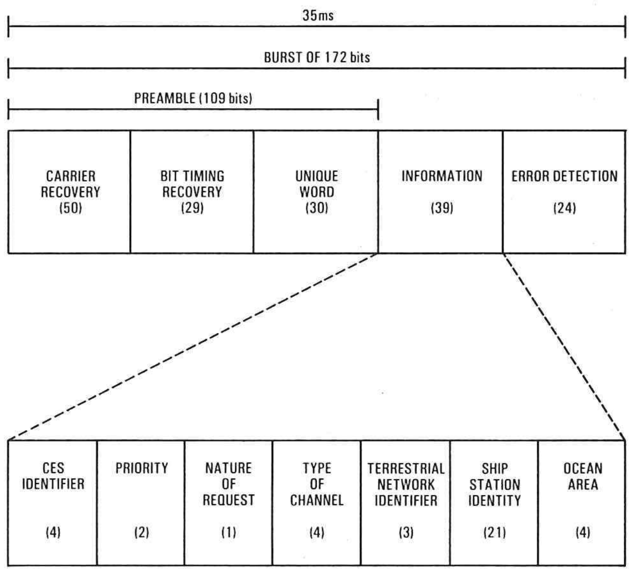


FIG. 19—Call set-up and R2 interface for ship-to-shore telephone call

information in the channel-type field of the *request* message is used by the SCP to allocate the equipment required for the call. A *request-for-assignment* message is then sent by the SCP to the NCS in the signalling channel of the UK CES's TDM carrier. However, if the equipment at Goonhilly Downs is fully occupied a *congestion* message is sent to the NCS which retransmits it on the common TDM channel to the ship. If the call has been identified as a distress call, an existing call through the ACSE is pre-empted by the SCP to make equipment available for the distress call.

On receiving a *request-for-assignment*, the NCS allocates a free channel to the call and signals that information to the



Notes: 1 The data rate is 4800 bit/s
2 The error detection coding is BCH 63,39
3 The figures in brackets indicate the number of bits allocated
4 The terrestrial network identifier is necessary only where there is a choice of common carrier

FIG. 20—Format of a *request* message

SES and CES on the common TDM carrier. Both stations then tune to the allocated channel and the CES transmits an SF tone on its carrier, to which the SES also responds by transmitting a similar tone to establish the continuity of the circuit.

Transmission of the SF tone is controlled by the SCP via the FM controller, which also reports back on the reception of the SF tone to the SCP. Having established the circuit, the CES turns off its SF tone causing the telephone in the SES to ring.

Raising the handset switches the ship's SF tone off and so signals the action to the ACSE, which then allocates time slots within the EFWS to the LIC connected to that modem. Notification of the SF tone going off is conveyed to the SCP, which commands the EFWS to send 1·5 s of *proceed-to-select* (*PTS*) tone to the ship. On hearing the *PTS* tone, the ship-board subscriber begins sending selection digits using the DTMF key-pad on the ship's telephone. As the *PTS* tone is sent, the EFWS allocates a DTR to the call, and instructs it to monitor the time slot assigned to the audio path from the ship. The DTR decodes the tone pairs and sends the recovered data to the CPU for forwarding to the SCP, where the selection is stored in the call register.

A check on the country code part of the selection is made by comparison with a table of allowed codes. If the UK code (*44*) is present, it is stripped off as it is not needed. The EFWS then seizes an outgoing circuit to the ISC in London and initiates in-band signalling. CCITT type R2 signalling is used over the circuit, the protocols of which are given in Reference 6.

Since the signalling is compelled, (that is, after the sequence has been initiated, the next tone pair in the sequence cannot be sent until requested to do so by a *backward* signal) the CPU must control the signalling generator in response to the *backward* signals and the selection sequence from the SCP. (It is possible that any exchange between the ACSE and the distant subscriber may request the repeat of one or more digits.) The response to all *backward* signals is within the capability of the EFWS CPU alone, without the need to refer to the SCP. When the distant subscriber answers, the duplex transmission path is established.

Clearing may be initiated by either calling or called party. However, for a ship-to-shore call, if the shore party clears first and the ship does not clear, there is a delay of 2 minutes before the connection to the ship is cleared by the ACSE. A delay is required because short clear-backs may be caused during certain actions by operators (for example, putting the calling party on HOLD while ringing an extension) before the required party is finally obtained. If the ship clears first, using the SF tone, clearing is initiated on the inland circuit. When the FM modem detects the disappearance of the ship's carrier, it reports this to the SCP via the LCS (DBE–LPU) which then assembles a *notification of ship clearing* message to send to the NCS on the Goonhilly Downs TDM carrier. This tells the NCS to remove the ship from the busy ship list, and remove the channel from the list of busy channels.

Throughout the call, the call register in the SCP records details of the calling and called parties, types of call, equipment used and the times at which the various stages of the call occur. At the end of the call this information is transferred to the Winchester disc, and is used later to compile billing and statistical information.

Ship-to-Shore Telex Call

A Telex call (see Fig. 21) is requested by the SES and accepted by the UK CES in the same manner as a voice call, but from that stage on the procedures differ.

Since Telex is transmitted by time slots in a TDM or TDMA frame, and separate TDM/TDMA carrier frequencies are assigned to each CES, it is the responsibility of the CES to control the allocation of TDM/TDMA time slot pairs. Within the SCP software is a master table of all the equipment modules within the system and the current status of each is continually updated. From this table the SCP can allocate free TDM/TDMA time slots to the new call. This allocation is performed on a cyclic basis to ensure that time slots are not left unused for a long period, thus ensuring a measure of self-testing. Assuming time slots are available, the SCP nominates a TDM/TDMA pair for the call, enters the details in the call register and formulates an *assignment* message, which is transmitted to the NCS in the signalling channel of the CES's TDM carrier. The NCS re-transmits the *assignment* message on the common TDM carrier, which is monitored by both the ship and the CES. Shortly after transmitting the *assignment* message, the ACSE inverts the line-signalling conditions in the nominated TDM time slot from SPACE to MARK. This is known as the *satellite call transition* and is achieved by the SCP commanding the appropriate satellite-Telex–LPU of the LCS to change state. (The ship terminal clears down if it detects a SPACE to help protect the system against ship terminal faults, such as tuning to the wrong TDM carrier or transmitting in the wrong time slot). On receipt of the repeated *assignment* message, the ship tunes its TDM receiver and TDMA transmitter to the nominated TDM/TDMA pair of frequencies. Once synchronism with the received TDM channel has been achieved, the inverted unique word transmitted every sixth TDM frame is used to time the TDMA bursts which are transmitted back to Goonhilly Downs by the ship. On recognising the MARK transmitted by the CES, the SES also inverts the line-signalling condition of its transmitted TDMA bursts from SPACE to MARK. This transition, known as *satellite call connect*, serves as a continuity check. On receipt of the MARK from the ship the ACSE sends *GH INMARSAT*, the time and *WRU* (*Who are you?*) to trigger the ship's *answer-back*. Once the *answer-back* has been received, verified and stored in the call register, the ACSE transmits the message *GA+* to indicate to the ship's operator that he should key in his call-selection sequence.

The selection data from the ship is stored in the call register and the SCP commands an appropriate LPU in the LCS to select a Telex circuit to the gateway exchange. The inland Telex circuits use CCITT Type C signalling described in Reference 7.

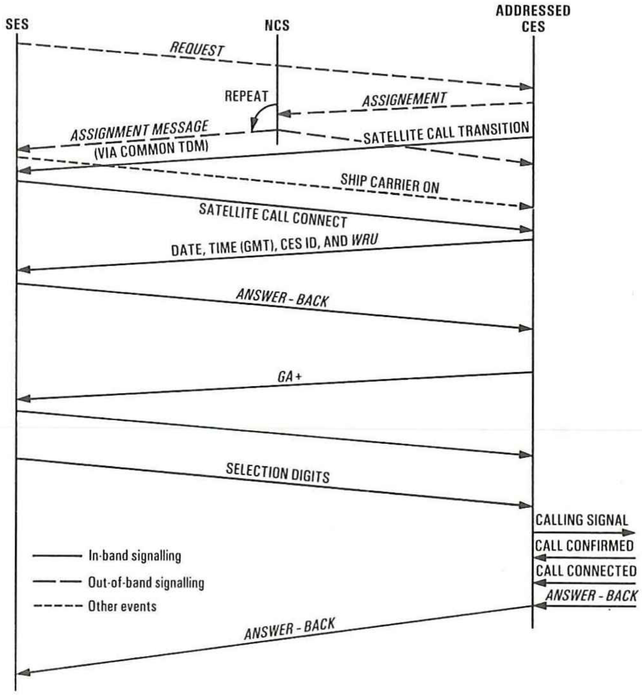


FIG. 21—Call set-up for ship-to-shore Telex call

The selection sequence from the ship, stored in the call register, is now sent to the gateway exchange, which acknowledges the sequence and proceeds to set up the required call. When the call has been set up, the gateway exchange returns a *call connect* signal to the ACSE which is used to instruct the LCS to complete the call connection.

The call may be cleared by either party. If the ship initiates clearing the satellite-Telex–LPU in the LCS detects the transition to SPACE, which is the *clearing* signal, and informs the LCS CPU, which in turn instructs the terrestrial-Telex–LPU in the LCS to send a *Type C clearing* signal and await the clearing confirmation from the gateway exchange. At the same time, the LCS-CPU informs the SCP of clearing so that the call register can be updated. Clearing of both satellite and terrestrial paths is completed separately by the appropriate LPU.

Once the ACSE is sure that the ship has ceased transmitting, the SCP transmits a *notification of ship clearing* message to the NCS on the CES's TDM signalling channel.

As for the telephony case, all details of the call are recorded in a call register in the SCP, and distress calls are able to pre-empt an occupied circuit if a free circuit is not available.

Shore-to-Ship Calls

Calls in the shore-to-ship direction follow a similar procedure to ship-to-shore calls except that the call is initiated by the seizing of an incoming inland circuit.

CONCLUSION

On 1 February 1983, the Goonhilly Downs CES commenced service with the Atlantic Ocean region satellite. Until that time, the UK traffic for this ocean region had been carried by the Norwegian CES at Eik. This station continued operation in the Atlantic Ocean region until the 14 February 1983 when it transferred operation to the Indian Ocean region satellite.

Under an agreement with the Nordic administrations, the UK CES at Goonhilly Downs will carry Nordic traffic to the Atlantic Ocean and the Norwegian CES at Eik will carry UK traffic to the Indian Ocean.

CORRECTION: In Part 1 of this article, Table 2 on p. 94 of the July 1982 issue of the *Journal* contains an error. The 'Required Output Power' for C-band should be 27·1 dBW and not 21·7 dBW as stated.

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Book Review

Leaky Feeders and Subsurface Radio Communications. P. Delogne. Peter Peregrinus Ltd. 283pp. 89 ills. £28·00.

This book provides an excellent introduction to a subject which has previously received little attention. It deals with the theoretical and practical aspects of mobile radio communications in mine, road and railway tunnels, where radio waves are normally severely attenuated unless assisted by wires or cables laid along the tunnel. One particular type of cable, known as a *leaky feeder*, is now being used extensively to overcome this problem. A leaky feeder is either an open pair or a loosely screened coaxial cable which, when fed directly with signals, provides fields (or leaks signals out) along its length, while in the reverse direction signals can be coupled into the line from nearby mobile transmitters. The performance of these cables is dealt with in detail in this book.

The author has been a leading expert in this field for many years. He is therefore ideally suited to write a book on what is a difficult subject to cover. To bring together meaningfully sophisticated electromagnetic theory with supporting practical results for the complex underground environments experienced in practice is an arduous task, but one which is well accomplished here. The book has been well thought out, with important sections highlighted, and gives a logical development of the subject starting from basic theory through finally to a discription of some actual working systems. My only criticism is that, in general, the system aspects could be developed in more detail, with possibly more attention given to a wider range of applications.

The book has a fairly broad and comprehensive opening chapter which introduces the reader to the subject in some detail. The second chapter develops, at length, the electromagnetic theory appropriate to subsurface communications. This is followed in chapter 3 by a look at the use of transmission-line models to explain the propagation characteristics in tunnels. The last 2 chapters are more practically orientated, dealing with various aspects of systems. Chapter 4 is devoted to communications at high frequency and below, and covers such topics as the effects of using different types of aerials, equipment performance, system design and optimisation of certain parameters. Chapter 5 looks at propagation and system structure at very high-frequency and ultra-high frequency. This is mainly concerned with the use of leaky feeders and, therefore, considers such aspects as attenuation along the feeder, coupling loss between cable and aerial, signal distribution alongside the feeder and the use of leaky-feeder sections in coaxial lines.

This book is ideally suited, and can be highly recommended, as a reference source for those working in the field of mining communications, not only for electromagnetic theoreticians and research students but also for practicing engineers. However, there are other fields arising where directed signal coverage is of increasing interest, and so this book is likely to have a wider appeal in the future.

A. J. MOTLEY

Telex–Packet Switching Interworking in the UK

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This article describes the new British Telecom interworking facility—the Telex network adapter (TNA)—which enables users of the UK Telex network to communicate with users of the packet-switched data network. It begins with a discussion of the design constraints and then describes the Telex and packet interfaces. The article goes on to describe the methods of calling-customer and called-customer identification and the charging principles involved. The methods of accessing the TNA and the selection numbering schemes used for both packet and Telex originated traffic are detailed and the call set-up, data transfer, and clear-down phases of interworking calls are discussed. The article ends with a description of the TNA equipment.

INTRODUCTION

British Telecom (BT) has recognised that with the development of its various networks—the public switched telephone network (PSTN), the public switched Telex network (PSTxN), the packet-switched data network (PSDN) and the integrated services digital network (ISDN)—there is a need for interworking between them, particularly for non-voice services; Telex-to-packet interworking is one of a number of network interworking combinations currently being implemented by BT.

After the PSDN became operational in the UK with the implementation of the packet-switched service (PSS)*, it became obvious that there was a demand for Telex users to be able to gain access to and from the PSDN. As with the introduction of any new service, it was difficult to forecast accurately the demand, but it seemed clear that the provision of an interworking capability was needed to enable customers who have a Telex terminal to gain access to hosts connected to the PSDN and, in particular, to those offering electronic mail services and databases. Also required was the ability for users of the UK Telex network and users of the PSDN to communicate with each other. BT is not the first administration to provide this interworking combination; Telex-to-public-data-network interworking systems are installed already in West Germany, Belgium, the USA, and Singapore, and are under development in several other countries.

The Telex-to-packet interface equipment, known within BT as the *Telex network adapter* (TNA), was developed by Plessey Controls Ltd. (PCL) and is based on their 4660/20 Telex switch with a moderate amount of additional software development.

In addition to the network interworking combinations outlined above, service interworking requirements are also receiving attention. For instance, the Teletex service has been defined to have a basic requirement of interworking with the Telex service. The BT Teletex service is parented on both the PSTN and the PSDN. Telex-to-Teletex service interworking requires the processing of data above the network protocol layers of the open systems interconnection (OSI) 7-layer model†† which a network interworking device such as the TNA is not designed to provide. Intercommunication between the Telex and Teletex services also requires the interconnection of the PSTxN with the PSDN and, indeed, with the PSTN, but this is the subject of a separate development within the UK known as the *conversion facility* (CF). To complete the circle, the Teletex service also requires the interconnection of the PSTN with the PSDN, and the device that will provide this interface has been given a name similar to that of the TNA—the packet network adapter (PNA).

It is forecast that the use of the Telex service, in its present form, will begin to decline in the mid-1980s because of the migration of traffic to other text communication services that offer various advantages such as higher speed, the International Alphabet No. 5 (IA5) character set, and the detection and correction of transmission errors. These newly emerging alternative services include Teletex, electronic mail (for example, DIALCOM and PSSMAIL), and fast facsimile. The provision of the TNA and the possibilities for intercommunication that it opens up for users of the Telex service are seen as part of this evolutionary process.

DESIGN CONSTRAINTS

A primary aim of the design of the TNA was the use of the discreet black-box approach so that the interworking function would be performed with minimal or no change to either network. Additional facilities were restricted in order to minimise the software development timescale and to introduce the service as soon as possible. The need to provide service at an early stage necessitated keeping changes to a minimum and compromising on the engineering implementation.

With these new network interconnection facilities, it is possible for a Telex customer to initiate a call to a packet terminal or to a character terminal via a packet assembler/disassembler (PAD). It is similarly possible for a customer of the packet network to initiate a call to a Telex terminal. The TNA acts as a PAD and performs code and speed conversion. Telex-to-Telex working through the TNA was not a design objective of the TNA and is not technically feasible with this equipment. Call charging facilities are not required within the TNA equipment since charging is accomplished elsewhere in the networks.

With 90 000 UK Telex terminals and a rapidly growing PSDN, a significant level of traffic between the networks is anticipated. However, until the service was operational, the demand could not be easily estimated and hence a relatively small provision was initially planned. The TNA is connected to the PSDN by two X75** links and 64 Telex trunks, which can be easily expanded to 128 Telex trunks without major change. It will be possible to provide a second TNA if required.

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* Also known as *Packet SwitchStream*

†† Information Processing Systems — Open Systems Interconnection Model — Basic Reference Model, Draft International Standard — ISO/DIS7498, Apr. 1982.

** International Telegraph and Telephone Consultative Committee (CCITT) Recommendation X75 defines the protocol to be used on interfaces linking separate public packet services

PHYSICAL NETWORK INTERFACES

Telex Interface

The choice of an access code that would route calls from anywhere in the UK Telex network to a common point in order to access the TNA was necessary. It was decided to use the international Telex assistance level 200, with access to the TNA equipment being provided off level 8.

A site in a London exchange was chosen for the TNA because

(*a*) direct Telex routes are available from London exchanges to and from all other inland exchanges,

(*b*) direct access to and from the international Telex gateway exchanges in London may be required, and

(*c*) a large proportion of the traffic requiring the interworking facilities is expected to originate in London.

The exchange chosen was Fleet in the City of London. There are 32 Telex trunks into the TNA and 32 Telex trunks from it, and the general signalling protocol is to CCITT Recommendation U1 Type B using dial selection as currently used in the inland Telex network.

Packet Interface

The TNA is connected to the PSDN by 2 tandem X75 links operating at 48 kbit/s to one packet-switching exchange (PSE). Only one of the links is used at any time and the second is provided for redundancy. The PSE used is in Baynard House, London. The TNA appears to the PSDN to act as a remote PAD, in accordance with the so called *Triple X* CCITT Recommendations X3, X28 and X29. Recommendations X3, X28 and X29 respectively define: the PAD facility; the interface for a START/STOP mode asynchronous terminal accessing a PAD; and the procedures for the exchange of control information and user data between a PAD and a packet-mode terminal or another PAD. Full implementation of Recommendations X3, X28 and X29 was not necessary. The TNA provides a fixed PAD profile with the exception of a single parameter, thus avoiding the full complexity of Recommendation X28. The advantages of acting as a PAD is that it identifies to other data terminal equipments (DTEs) the type of service the TNA provides and the low data signalling rate as well as enabling them to interrogate the PAD parameters and make use of PAD command facilities. It also provides a fixed framework within which to handle the PSDN–PSTxN interface.

CALL SET-UP PROCEDURES

The overall call set-up procedures described in the following paragraphs are summarised in Figs. 1 and 2.

Accessing The TNA

Telex-to-PSDN Connections

The Telex customer uses a 2-stage selection procedure. First, access to the TNA is gained by dialling the code *2008*. Secondly, the Telex customer inputs a single dial digit *3*, which allows access to the PSDN. The use of a dial digit other than *3* following *2008* gives access to TNA special services.

Packet-to-Telex Connections

Calls from terminals on the PSDN in the UK to Telex terminals are routed to the TNA by the use of the digit *8*, as defined in CCITT Recommendation X121 for use with interworking with Telex networks. The *8* becomes the first digit of the 4-digit field normally filled by a data network identification code (DNIC) within the called DTE address field of the *call request* packet.

Selection Numbering Schemes

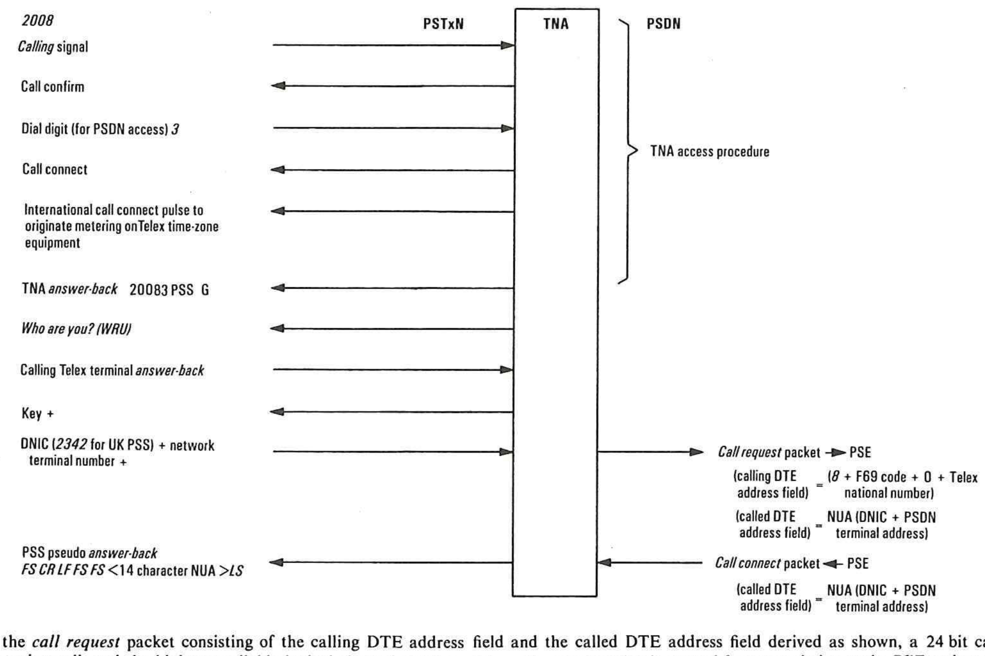
Telex-to-Packet Connections

After the completion of the TNA access procedure, the *call connect* pulses are returned and there is an exchange of *answer-back* codes. The remainder of the selection is the keyboard second-stage selection delimited by an *end-of-selection* (*EOS*) character. The selection is in the form:

DNIC+network terminal number+.

This mode of selection applies to all Telex originated calls and even calls to a UK DTE use the full international address including the UK DNIC, *2342*, where *234* is the data country code and the final *2* is the digit allocated to the UK PSDN. Overseas DNICs will initially be barred.

Several problems existed for the overseas-Telex-to-UK-PSS category of traffic. These concerned the billing of overseas Telex customers, the establishment of international



Note: The TNA forms the *call request* packet consisting of the calling DTE address field and the called DTE address field derived as shown, a 24 bit call serial number incremented for each outgoing call, and the highest available logical channel number. The *call request* packet is queued for transmission to the PSE and on receipt of the *call connection* packet the call enters the data-transfer phase

FIG. 1—Telex-to-packet call set-up sequence

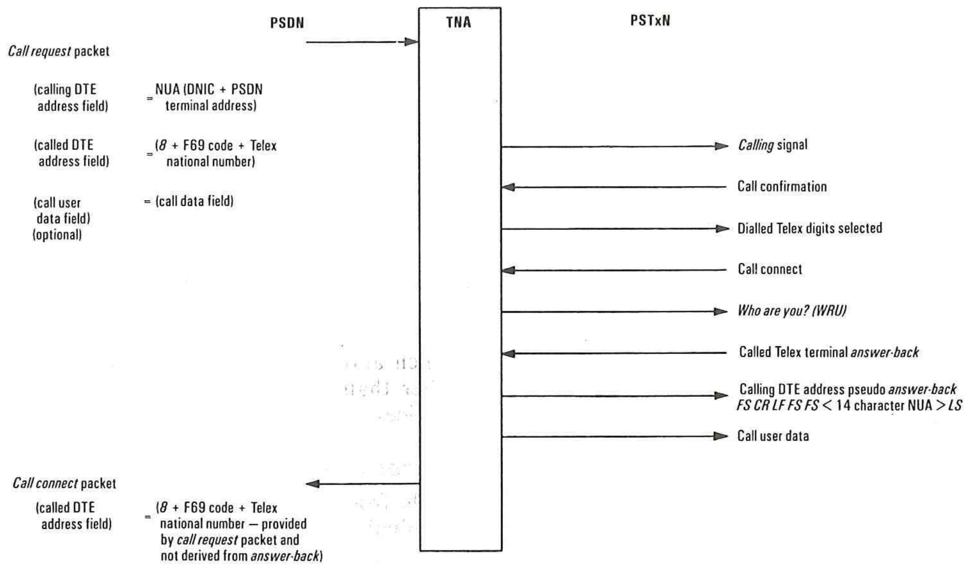


FIG. 2—Packet-to-Telex call set-up sequence

bulk accounting procedures and agreements, and the recognition of non-standard *answer-back* codes. Initially, it is not planned to offer access to the TNA to incoming international Telex customers, but this category of traffic is planned to be introduced later when the above problems have been resolved. Market research conducted on behalf of BT has revealed that overseas international Telex working, especially incoming, will greatly increase the attraction of the TNA facility to the customer.

Packet-to-Telex Connections

For UK PSS originated calls in accordance with Recommendation X121, the TNA access procedure is followed by the international Telex country code (F69 code) and the national Telex number of the called terminal. Thus, to call a UK Telex terminal, the selection would be

51<*UK national Telex number*>.

The TNA then performs the outgoing routeing in the Telex network. Following the receipt of the *call connect* pulse, there is an exchange of *answer-back* codes.

Initially, the use of the UK Telex DNIC code, *2348*, followed by the Telex number also in accordance with Recommendation X121 was proposed and, in fact, had been implemented, but *851* was preferred for operational reasons. The aim was to identify the called customer by using the normal international number used to identify that customer on the destination network. However, for calls originated from terminals on an overseas packet network to Telex terminals in the UK, the UK Telex DNIC format will probably be adopted in most cases. Initially, the TNA is being operated as a purely inland service, but it is expected that incoming international packet-switched network and outgoing international Telex network access will be added later.

CUSTOMER IDENTIFICATION

Customer identification is used during call establishment to inform the calling terminal of the identity of the called terminal and to identify the calling terminal for charging purposes.

Calling-Customer Identification

Telex-to-Packet Connections

In the Telex-to-packet direction, the Telex caller's identity is provided by the terminal's *answer-back* code captured during call establishment. The national identification code letters derived from the *answer-back* code are converted to the F69 code appropriate to the calling Telex terminal, and may be 2 or 3 digits in length. For example, the UK national Telex identification code is a *G* and this is converted to the UK F69 code, *51*. The complete network user address (NUA) comprises the prefix digit, *8*, followed by the F69 code, together with the national Telex number of the calling terminal (which may be 5, 6 or 7 digits in length) also obtained from the *answer-back* code. The format of the NUA is defined as commencing with a 4-digit DNIC, followed by the Telex number unique to the user. To satisfy this requirement, the DNIC is represented by the digits *8510* followed by the national Telex number.

Consideration was given to the use of a customer input network user identity (NUI) instead of using the Telex *answer-back* code. This NUI would have been converted by the TNA to an NUA by using tables of valid NUIs. The use of an NUI offers advantages of giving Telex customers security against fraudulent use, and makes charging an easier problem to overcome. It also makes it possible for the Telex customer to make use of a number of Telex terminals and be charged on a single NUI account. The use of NUIs ensures that only known users, issued with a NUI could use the facility and would allow the PSS billing system to directly issue billing advices based on the registered customer's name and address. Thus, the use of an NUI would have the advantage of compatibility with current PSS practice for terminals accessing via the PSTN. It does, however, imply the disadvantage that Telex customers would receive bills for TNA calls to cover use of the TNA and PSDN in addition to their ordinary bill for metered units arising from use of the PSTxN.

However, the NUI concept was eventually abandoned because it had a significant impact on development timescales as a result of its requirement for more complex protocols and the additional complexity of the necessary tables and commands. Implementation of the NUI facility would have limited the TNA in capacity owing to the need to search for the input NUI for validation and to obtain the NUA. A maximum of only 5000 customers could have been accommodated. Use of the NUI facility also has the disadvantages of the additional cost of maintaining the NUI list, and a longer call set-up time.

Packet-to-Telex Connections

In the packet-to-Telex direction, the identification of the calling DTE is given by the NUA provided in the calling DTE address field of the *call request* packet. It is stored for the duration of the call to generate a pseudo *answer-back* code if requested by the calling Telex terminal.

Called-Customer Identification

Telex-to-Packet Connections

In the Telex-to-packet direction, when the *call connect* packet is received by the TNA, the called DTE address is used to form the called terminal's identity. This identity is returned to the calling Telex terminal as a pseudo *answer-back* code. The format of this pseudo *answer-back* code is

FS CR LF FS FS <*14 character NUA*> *LS*

where *FS* is the figure-shift character,
CR is the carriage-return character,
LF is the line-feed character, and
LS is the letter-shift character.

The NUA is extracted from the called DTE address field of the *call connect* packet. NUAs which are less than 14 characters in length are padded out using *LS* characters. The NUA is stored by the TNA for the duration of the call to allow the generation of the pseudo *answer-back* code during the data-transfer phase of the call if requested by the calling Telex terminal.

Packet-to-Telex Connections

In the packet-to-Telex direction, the called terminal identity is not derived from the called terminal's *answer-back* code, but instead from the called DTE address field of the *call request* packet. However, a terminal on the PSDN can verify connection to the correct Telex terminal customer by use of the *enquiry* (*ENQ*) character. This is converted by the TNA to the International Telegraph Alphabet No. 2 (ITA2) character, *WRU*, which triggers the Telex terminal's *answer-back* code; this is then transmitted to the PSDN terminal in a separate data packet.

DATA-TRANSFER PHASE

During the data-transfer phase, the TNA performs packet assembly, disassembly and code conversion in accordance with CCITT Recommendations X3, X28, X29 and X30.

Telex-to-Packet Connections

Telex characters are converted from ITA2 characters to IA5 characters with even parity and stored sequentially in data packets. Since the original specification of the TNA was produced, it has become apparent that Telex users may need to access IA5 characters that have no direct ITA2 equivalent. These characters (for example, lower case and control characters) are sometimes required for the control of some of the application programs (such as database managers) that are available on the PSDN host computers. It is expected that a future enhancement to the TNA will, therefore, add a facility whereby defined strings of ITA2 characters are converted to those IA5 characters that are not, at present, accessible. A fixed PAD profile is used by the TNA to describe Telex terminals and only one PAD parameter (reference number 8) may be altered by remote PAD or packet-mode terminals on the PSDN; it is set to one on receipt of the *break* signal from the Telex terminal.

Packets are forwarded, subject to flow control, when they reach their permitted size (128 data characters) or on expiry of a delay (provisionally set at 7·5 s) without receipt of a Telex character. Packets are also forwarded following the receipt of reserved Telex characters such as *BELL* or *WRU*, or special combinations of characters, for example, *CR LF*, and on receipt of the *WWWWW* break sequence.

When flow control prevents the forwarding of further data packets, the TNA stores a limited number of packets and, when this limit is exceeded, the TNA transmits the *BELL* character followed by a sequence of *P* characters to the Telex terminal until the receipt of Telex data ceases; it then transmits the service message *MOM* to the Telex terminal. The Telex terminal receives the service message *GA* to request further data when buffer storage becomes available.

Packet-to-Telex Connections

The contents of the user data field of the data packets received by the TNA are transmitted to the Telex terminal. The characters are converted from IA5 to ITA2, ignoring parity, according to CCITT Recommendation S18, and transmitted at 50 baud. The TNA inserts shift characters and the *CR LF* sequence when appropriate.

The TNA detects data packets with the Q bit set to 1; these are interpreted as PAD messages and acted upon by the TNA. Flow control is used to regulate the receipt of packets. The TNA acknowledges the receipt of each data packet with a *receive ready* packet when all the contents of the data packet have been transmitted successfully to the called Telex terminal. Since most Telex terminals use half-duplex working, the TNA is designed to cease outputting data to the Telex terminal if characters are detected on the input to the TNA from the Telex terminal. Data output will continue when Telex data ceases to be received by the TNA.

RESET

When a *reset request* packet is received from the packet terminal, all current user data held in the TNA is discarded. The TNA transmits a *reset service* signal to the Telex terminal and a *reset confirmation* packet to the originator of the *reset request* packet.

The TNA generates and transmits a *reset request* packet itself as required by CCITT Recommendation X75, if packet-level protocol errors occur and the *reset service* signal is sent to the Telex terminal. The TNA also transmits a *reset request* when the break sequence is received from the Telex terminal. The TNA then awaits receipt of a *reset confirmation* packet.

CLEAR-DOWN PHASE

Clearing initiated by the packet terminal or network

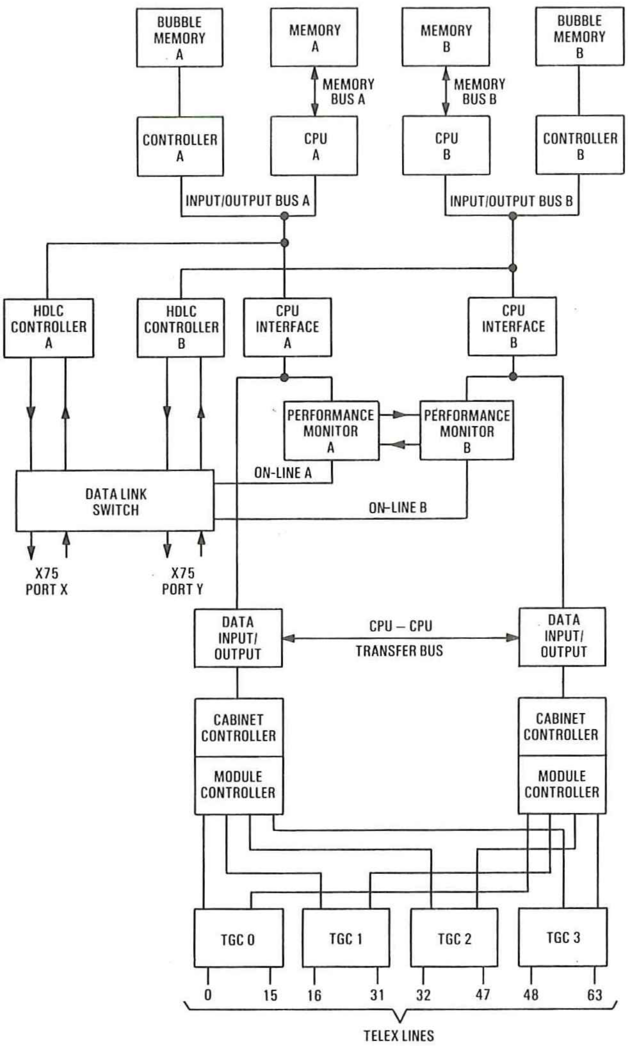
The TNA clears the call on receipt of either a *clear request* packet, an *invitation-to-clear* PAD message, or an *error* PAD message. On receipt of an *invitation-to-clear* PAD message, the TNA continues transmission to the Telex terminal until all packet data has been output before initiating clearing. On receipt of an *error* PAD message, the TNA clears the call in both directions.

Clearing initiated by the TNA

The TNA clears the call and generates a *clear request* packet in a number of circumstances, which include call set-up failures, systems failures due to internal congestion, and restart. The TNA inserts a diagnostic code field relevant to the packet network in the *clear request* packet to identify the clearing cause. On receipt of a *restart* request, the TNA returns confirmation and clears all calls. The TNA may initiate a restart itself under some conditions of equipment failure.

Clearing initiated by the Telex terminal

When clearing is initiated by the Telex terminal, the TNA clears the call, and transmits a *clear request* packet with the clearing cause set to *DTE Clearing.*



CPU: Central processor unit

FIG. 3—Block diagram of TNA configuration

CHARGING

Charging functions are not performed by the TNA since these are handled by equipment in the Telex and packet networks. Briefly, the principles of charging are as follows.

Telex Originated Calls

For Telex originated calls, the customer is charged separately for the PSTxN, and PSDN portions of the call. For the Telex portion of the call, the customer is metered on a distance-dependent basis from the time the TNA is accessed. This follows the same principle as applied to calls accessing the PSDN from the PSTN where a customer has his telephone call metered from the moment that access to a PAD is provided. For the PSDN portion of the call, the Telex *answer-back* code is used to identify the calling Telex terminal. This approach requires the output of the PSS billing program to be processed manually by Telex billing centres. The PSS billing program charges the Telex customer a PSDN access charge, and, in addition, he is charged for the data transmitted on the basis of both volume and duration in accordance with normal PSDN practice.

PSDN Originated Calls

For PSDN originated calls, the PSS customer pays normal PSDN volume and duration charges. In addition, the PSDN customer pays a PSTxN access charge and a distance-dependent charge for the Telex element of the call. Billing for the entire call is undertaken as part of the PSS billing program suite.

EQUIPMENT DESCRIPTION

The TNA equipment is based on the PCL 4660/20 Telex switch, which has already been installed in the UK Telex network as inland Telex line concentrators. This is the smallest version of the family of PCL's 4660 systems; larger versions have been in operation for some years providing international gateway facilities. Minimal hardware development was required.

The basic 4660/20 system comprises a fully-redundant stored-program control non-blocking time-division multiplexed switch. The equipment is controlled by a General Automation 16/240 microprocessor through which all signalling and data traffic passes. Dual redundancy extends down to the terminator module controllers each of which controls 4 terminator group controllers (TGC). Each TGC serves 4 terminator cards, each of which comprises 4 trunk terminations. The TGC performs certain low-level tasks associated with character transmission and signalling, thus relieving the load on the centre microprocessor. Typical of these tasks are the serial-to-parallel and parallel-to-serial conversion of characters, decoding of dial selection information, character distortion measurement, and detection of calling and clearing conditions.

The equipment was supplied with 128 Kwords of main memory backed up by 128 Kwords of bubble memory for use in the event of a cold restart being required.

The TNA equipment is configured on the on-line/warm-stand-by principle (see Fig. 3) Any item of equipment affecting more than 16 ports is duplicated. The high-level data link control protocol (HDLC) ports for the X75 links are duplicated. The on-line system handles all functions of the TNA. Any on-line component failure likely to cause degradation or loss of service is detected by hardware or software and causes a switch-over. The warm-stand-by equipment then takes over. All calls in progress are cleared down, but the warm-stand-by equipment has a record of the cleared calls and sends appropriate service signals to the customers affected.

CONCLUSION

The provision of the TNA–PSS interworking service has paved the way for Telex users to access PSS mailboxes, and databases. In addition, the modern executive on the move carrying a portable data terminal incorporating an acoustic coupler will be able to access all Telex terminals from any ordinary telephone by using the PSS dial-up facility, providing he has an NUI registered on the PSS.

Future plans involve combining the PSS-to-Telex interworking service with store-and-forward facilities.

The TNA is seen as an important contribution to the age of information technology and is now being introduced into service by BT.

ACKNOWLEDGEMENT

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The European Communications Satellite Multi-Service Transponder

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This article describes the multi-services transponder of the European Communications Satellite (ECS) and the alternative ways in which the transponder can be exploited. This article is based on a paper presented at the Institution of Electrical Engineers (IEE) Communications '82 Conference, Birmingham[1] and is reproduced with the permission of the IEE. Small-dish satellite services are being marketed by British Telecom in the UK under the name SatStream, and will be suitable for the full range of telecommunications activity. SatStream Europe, which will use capacity on the ECS, will be available from 1984. Access to the satellite will be via small-dish earth terminals located on or near customers' premises for their sole use, or near several customers for their shared use.

INTRODUCTION

The decision to proceed with the European Communications Satellite (ECS) was taken by the principal European Telecommunication Administrations and their Governments in 1979. Under an agreement between the two organisations, the European Space Agency (ESA) is responsible for specifying, procuring and launching these satellites, and Interim EUTELSAT for operating them. Five satellites are planned to provide secure communications for the period 1983 to 1993. Principally, the satellites are designed to provide capacity for trunk telephony traffic and television distribution, and will operate to earth stations of antenna diameter 16–19 m in the 14/11 GHz shared frequency bands.

A further decision was taken in December 1980 by EUTELSAT to accept an offer by ESA to modify 4 satellites, flights F2 to F5 (not F1, because of time constraints), to provide communications facilities to small earth stations. Such facilities comprise a wide range of bit rates capable of supporting data, voice, audio and videoconferencing services, collectively referred to as *satellite multi-services*. The modification consists of providing 2 extra transponders on each satellite, operating in the 14/12 GHz bands, which are not shared with the terrestrial radio-relay service and are thus well suited for operation with small earth terminals. The modification is made possible by an increased payload capability of later variants of the *ARIANE* launcher. Fig. 1 shows a block diagram of the communications payload, and the transponder plan of the modified satellite payload is shown in Fig. 2.

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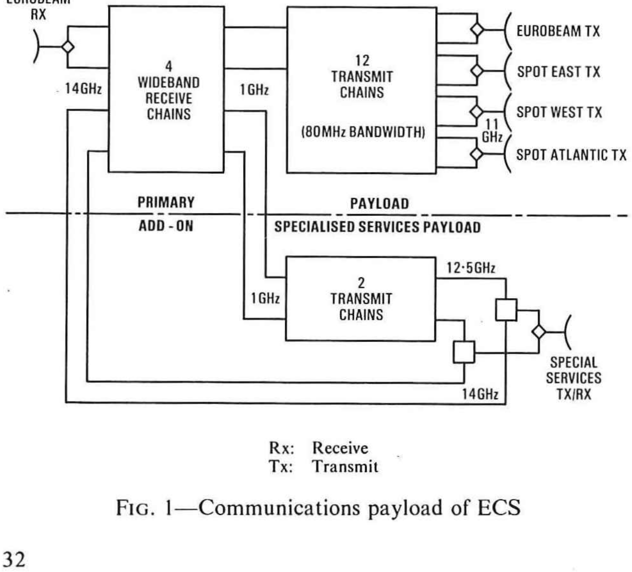


Rx: Receive
Tx: Transmit

FIG. 1—Communications payload of ECS

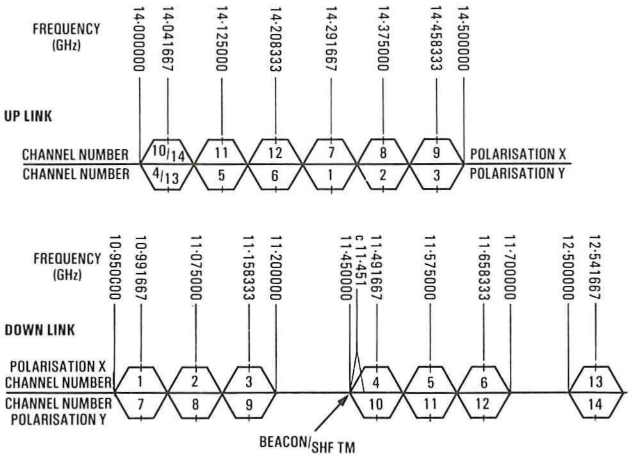


FIG. 2—ECS transponder frequency plan

The additional ECS transponders have 20 W travelling-wave amplifiers (TWAs) driving an antenna whose coverage area is shown in Fig. 3. The same antenna operates for the receive direction, and a power flux density of $-94 \cdot 2\,\mathrm{dBW/m^2}$ is required to saturate the transponder. The usable transponder bandwidth is 72 MHz.

SYSTEM CHARACTERISTICS

Communications satellites have to be accessed by many earth stations simultaneously to provide broad-based networks with the maximum possible connectivity. The 2 access methods under consideration are frequency-division multiple access (FDMA) and time-division multiple access (TDMA). The capacity of a satellite and the characteristics of the earth stations operating to it depend on the access method. Satellite multi-services provided by the ECS are intended for major business users and will be based on digital channels at data rates of 64 kbit/s and above.

It is assumed that the modulation method adopted for a multi-service transponder providing digital channels is phase-shift keying (PSK), this being the optimum for a satellite environment when power is limited. The level of modulation, or number of permissible phase states of the carrier, is the subject of further optimisation.

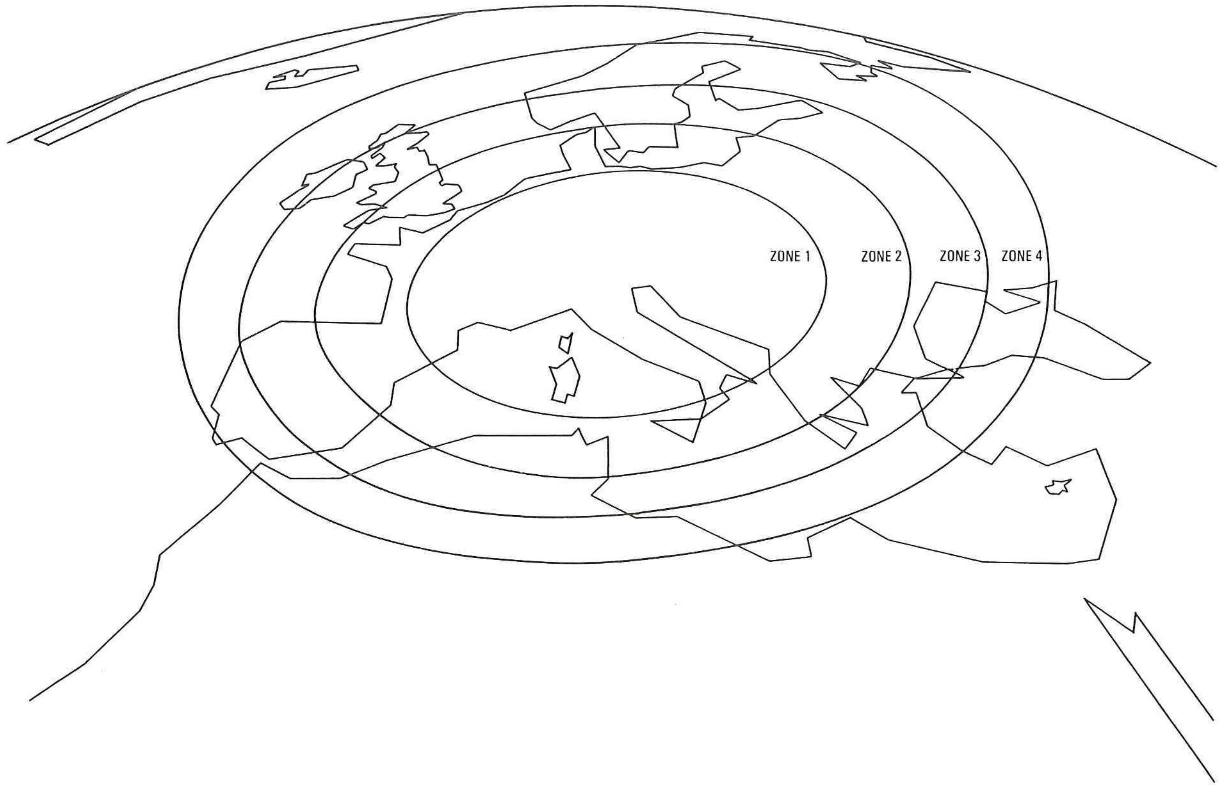


FIG. 3—Multi-service coverage area

Capacity

The maximum capacity of a satellite transponder is a function of the bandwidth and the equivalent isotropically radiated power (EIRP) of the transponder, and the ratio of antenna gain to system noise temperature (G/T) and the EIRP of the earth stations. Fig. 4 shows the capacity/satellite EIRP relationship for 3 types of PSK modulation; namely, 2-, 4- and 8-phase PSK. The knee that joins the sloping segment of each capacity curve to the horizontal segment is the point at which the transponder changes from the power-limited to the bandwidth-limited region. For values of satellite EIRP less than X (see Fig. 4) it does not matter whether 2-phase or 4-phase modulation is used. For values less than Y, 4-phase PSK gives up to twice the capacity of 2-phase PSK and for values greater than Z, 8-phase PSK can give up to 3 times this capacity.

In 8-phase PSK, however, the carrier power has to be enhanced to overcome the increased sensitivity which arises from the need to distinguish between permissible phase states spaced at 45° intervals. The required carrier power enhancement is not matched by a similar increase in the bit rate, resulting in a less efficient use of available power than for 2-phase and 4-phase PSK. For this reason 8-phase PSK is not of interest in the present power-limited satellite systems.

The actual capacity obtained from a transponder increases with the G/T of the earth station. This can be maximised by reducing the system noise temperature T as far as practicable, and by increasing the antenna gain G. Fig. 5 shows how the transponder capacity varies according to the earth station G/T ratio, and to the antenna diameter assuming a clear sky system noise temperature of 220 K.

There is a relationship between the satellite transponder parameters of power and bandwidth and the earth terminal's G/T such that the operating point on Fig. 4 can only be determined when the earth terminal G/T is known. It is useful to introduce a factor A which relates satellite EIRP

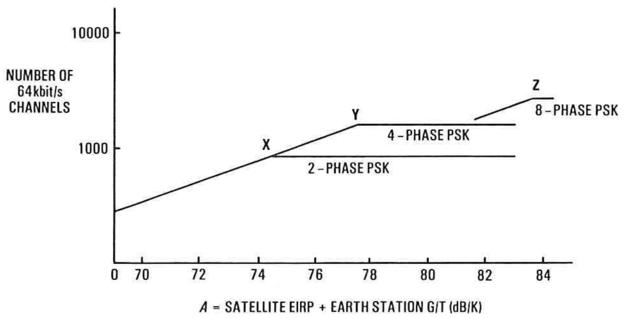


FIG. 4—Relationship between capacity, power and bandwidth

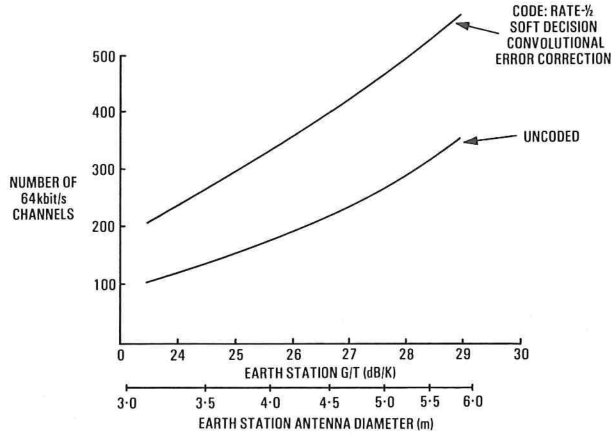


FIG. 5—Variation of transponder capacity with earth station G/T

and earth terminal G/T as follows:

A = (Satellite EIRP × Earth terminal G/T) Watts/K

which becomes the sum of these parameters when expressed in decibels. By plotting transponder capacity against A, as is done in Fig. 4, with a knowledge of its EIRP and bandwidth, it is possible to choose the earth station G/T for an optimum transponder capacity. This is normally chosen to correspond to an operating point at or close to a knee in Fig. 4 where both power and available bandwidth are fully utilised.

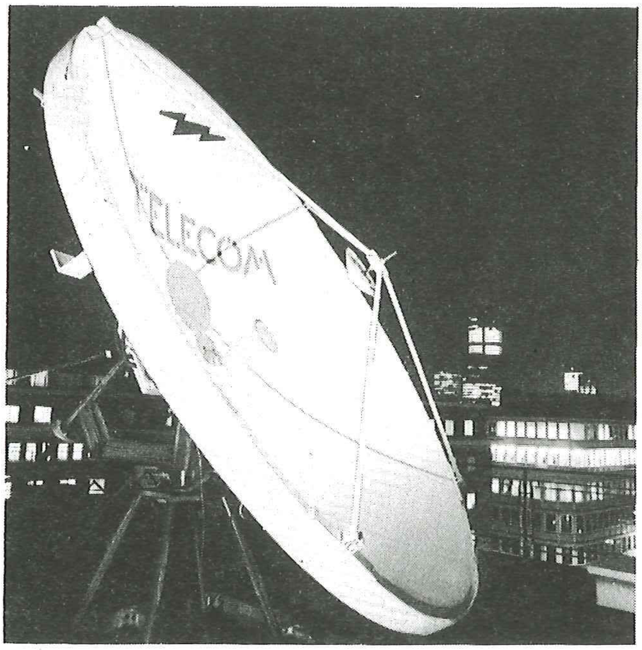
It should be noted that the sloping segments of Fig. 4 could be moved upwards either by applying a more powerful form of forward error correction (FEC) or by accepting a higher bit error rate on the satellite link. The horizontal segments can be moved downwards by reducing the usable bandwidth of the transponder. The converse of these two aspects can obviously apply.

Choice of Earth Terminal Size

The earth terminal can be chosen to optimise capacity according to the theoretical approach of the previous section. This leads to a sensitive earth terminal with an antenna diameter in excess of 7 m, even for the example given, which assumes a powerful FEC code. This conclusion is not surprising and explains the present dominance of systems with large gateway earth stations usually fed by traffic collected from an entire country or region.

National or regional earth stations are not suitable for the earth segment working to a multi-service transponder because terrestrial feeder networks would have to support all the multi-services carried by the transponder. At present, this is not possible and the earth stations must be positioned closer to the point of origin of the traffic, either to the customer's premises or a location nearby (see Fig. 6).

In general, it would prove both uneconomic and impractical to deploy earth terminals with antenna sizes of 7 m or more close to customers' premises. The earth terminals would be costly because of the size of the large supporting structure and a tracking system. Therefore, it would be more practical to position earth terminals close to customers' premises if the diameter of the antenna is reduced. Clearly this is more feasible because the cost of the earth terminal would be lower, but the capacity of the transponder would also be reduced according to the relationship of Fig. 4. If moving the earth terminal close to the customer also means that the number of terminals must increase then, with a given transponder capacity, there is a lower average terminal capacity.



Note: This 3 m small-dish earth terminal on the roof of the Financial Times' building in London was used in an experiment whereby pages of the newspaper were transmitted via the orbital test satellite to Frankfurt, Germany, where the newspaper's international edition is published.

FIG. 6—Small-dish earth terminal

There must exist a compromise between the high-capacity national or regional earth station and the versatile small-dish earth terminal. This compromise appears to consist of an earth terminal which forms the centre of a local network that collects traffic by means of dedicated cable or radio systems capable of handling the variety of multi-services present. The antenna of the terminal would be sufficiently large to enable a transponder capacity of 400–500 64 kbit/s channels. The traffic loading per terminal would be high because of the high transponder capacity, and the limitation of the number of terminals, made possible by sharing.

A suitable terminal to meet this compromise solution would have a G/T of 28 dB/K corresponding to an antenna diameter of 5 m.

With these earth station parameters, the transponder is operated in the power-limited region at a sub-optimum point where it does not matter, theoretically, whether 2-phase or 4-phase modulation is used. In practice, 2-phase PSK allows a simple demodulator of either coherent or differential operation, and 4-phase PSK would be compatible with existing designs working in the INTELSAT single-channel-per-carrier (SCPC) system, which employ coherent detection.

SATELLITE ACCESS METHODS

Assuming a 5 m antenna earth station working to the ECS transponder, the technical aspects of using FDMA and TDMA are now considered.

FDMA is a method of access in which several carriers, each on a different frequency, are handled simultaneously by the transponder. Each carrier may contain either a single data or voice channel, or a number of multiplexed channels. Either analogue or digital techniques can be used for modulation and multiplexing. In FDMA it is possible for carriers on the same transponder to differ in their modulation and multiplexing methods, and in their power level and bandwidth, since each carrier is essentially independent of the others.

In TDMA, a particular frequency is accessed by several carriers, each transmitted on that frequency in a sequential manner to avoid overlapping in time. The dependence on accurate timing makes TDMA most suitable to digitally encoded data, and all carriers in the same system must use the same transmission rate, modulation method and TDMA frame parameters. Usually a TDMA system is designed to occupy the whole transponder, but the use of a TDMA system on a frequency slot within an FDMA system is quite feasible.

The kind of traffic considered appropriate for satellite multi-services includes point-to-point and multipoint channels bearing digital data at rates covering 2·4 kbit/s to 1920 kbit/s, including $n \times 64$ kbit/s channels where n might take the value 1, 2, 4 or 8. Voice channels could be encoded using pulse-code modulation (PCM) or 32 kbit/s adaptive differential PCM. Circuits would be accessed by the customer via the CCITT† X21 digital interface, which can support various levels of demand assignment such as leased-line connections, a reservation service and full circuit switching within the satellite network. The choice of the level of demand assignment is a function of customer requirements, the structure of the satellite network and the complexity of the satellite access method.

† International Telephone and Telegraph Consultative Committee

Frequency-Division Multiple Access

Capacity

FDMA is generally thought to have a lower capacity than single-channel-per-transponder operation, such as TDMA, because of the need to back-off the satellite TWA to reduce intermodulation noise. However, the ECS multi-service system does not suffer this problem. The use of the standard 72 MHz transponder in a severely power-limited mode means that the occupied bandwidth is only one half of the total available, and intermodulation noise power can be arranged to be spread across the entire band, resulting in a signal-to-intermodulation-noise (C/I) ratio of 18 to 20 dB. This gives an improvement factor of about 3 dB effectively removing intermodulation noise as a critical factor, so that only minimal back-off is required. In the following analysis the ECS FDMA system is assumed to operate in the SCPC mode.

Error Correction

The provision of low channel rates (2 Mbit/s and below) allows powerful error-correction techniques to be used. A rate-1/2 soft decision convolutional FEC unit reduces the energy-per-bit-to-noise-power-density ratio (E/No) requirement per channel from 11 dB to 6 dB, providing a corresponding increase in channel capacity, as shown in Fig. 5. Any improvement of channel bit error performance is achieved by increasing the uplink power for that channel, thereby increasing its C/N ratio.

Power Requirements

Earth station power in an ECS SCPC system is of the order of 1 W per 64 kbit/s channel. However, at a typical earth station carrying a number of 64 kbit/s channels, a high-power amplifier (HPA) of 40–50 W saturated output power may be required to allow sufficient back-off to reduce intermodulation on the uplink. If provision for two 2 Mbit/s channels is included, an HPA of 250 W is required.

Earth Station Complexity

FDMA SCPC equipment is relatively cheap and inherently simple compared with that of TDMA. It enables provision of pre-assigned point-to-point and point-to-multipoint links, a service that can be enhanced by voice activation or digital channel activation by request from the customer's terminal equipment. This allows sharing of the satellite capacity, and can be achieved without recourse to a system management centre (SMC).

If a more flexible demand-assignment method were offered, such as circuit switching, this would require allocation of transponder capacity by an SMC. It would also involve active control of the frequencies transmitted and received by each earth station if, as is likely, the number of assigned channels exceeds the number of slots available.

Such a system could be considered to provide a circuit-switched service, but detracts from the inherent simplicity of FDMA in an SCPC mode. It is arguable whether a relatively complex FDMA or a simple TDMA system is optimum when this stage of the system evolution has been reached.

Non-Standard Earth Stations

The considerations so far have applied to a set of earth stations of the same G/T which could be described as standard stations. An FDMA system can accommodate non-standard earth stations with higher or lower G/T values than standard. Such an arrangement could be useful in a network in which all circuits are concentrated on a central station or where a large station wishes to broadcast information to many smaller ones. In the first example, the satellite power can be divided to provide a stronger signal to the small stations than can be returned to the central station.

In the second example, the trade-off between the large transmitting station and the small receiving station is obtained at the expense of other carriers that could have been accommodated in the transponder. This technique could also be used to give a specially good link performance on a particular route.

Multipoint

Point-to-multipoint connections are a special case of satellite systems and can be configured in a number of ways. In the FDMA mode it is quite feasible to connect links in 2 simple arrangements; namely, pure broadcast and point-to-*n*-point where *n* return channels are summed in the earth terminal access equipment. In this arrangement the multipoint circuit under the control of a customer-level protocol. The summation of return channels is passive and could be implemented by a logical AND function with inactive return channels set to logic level BINARY ONE.

Time-Division Multiple Access

Capacity

A TDMA system may operate with saturated satellite and earth station HPAs, and may even oversaturate the satellite TWA in order to minimise the effect of uplink fades on the downlink EIRP. No capacity reduction is needed on account of intermodulation, though the capacity limitations of earth station G/T and satellite saturated EIRP still apply.

Error Correction

In a single channel per transponder TDMA system all carriers in the transponder must work to the same transmission parameters and data structure, which can limit to some extent the ability of the system to vary the type of service that is provided. A single error-correction unit is shared by all channels and, because of the data rate involved, cannot be of a powerful type. In practice, it is difficult to reduce the E/No requirement by the use of FEC, but it can be used on an optional basis to provide an enhanced error-rate performance.

Power Requirements

TDMA systems are often considered to suffer the disadvantage of high uplink power requirements. It is true that each station has to transmit over the whole occupied transponder bandwidth, but the lack of intermodulation products allows the earth station HPA to operate near to saturation. A TDMA system using a 5 m antenna working to the ECS multi-service transponder would need an HPA power rating of about 1000 W.

The operation of the satellite TWA in saturation gives an advantage to the system in that the effect of uplink fades caused by propagation attenuation is only slightly reflected in the downlink. The TWA operates in a non-linear mode known as *compression*, and a 3 dB input attenuation causes only a 0·6 dB reduction of output power. The effect of uplink fades on link power calculations is considerably reduced, and burst-to-burst level variations at the earth station demodulators are minimised.

System Complexity

A TDMA system automatically gives all earth stations access to a common unit of bandwidth, and variation of channel assignments and routeing is achieved by time-plan processing, normally under remote control via specially configured control channels. Generally, if a high degree of connection flexibility is required, then TDMA is the better method.

Many different TDMA systems have been proposed

involving a wide range of control philosophy. There are 3 things all systems have in common:

(*a*) some form of burst synchronisation,
(*b*) management of the TDMA frame time plan, and
(*c*) allocation of terrestrial channels to the allocated satellite capacity.

Generally, a master station is needed to provide some or all of these functions. The INTELSAT and EUTELSAT TDMA systems for trunk telephony, for example, will use reference stations to generate the frame reference and to assist traffic stations to synchronise their transmitted bursts in the frame, but the time plan and terrestrial channel allocation is pre-assigned.

The TELECOM 1 system[2] will have a combined reference station and SMC, which synchronises all traffic stations, and allocates frame and terrestrial channel capacity on demand. A common-channel signalling facility is incorporated in the system to connect circuit-switched and reservation channels.

A further level of complexity is introduced when a TDMA system is used to provide access to packet-switched services, such as those using the CCITT X25 protocol, or to local area networks such as the Cambridge Ring or Ethernet[3]. Typical systems use a simplified synchronisation method, allocate total satellite capacity to each earth station on a fairly long-term basis, but access to the satellite capacity can vary on a frame by frame basis under local control.

Multipoint

TDMA systems can provide the forms of multipoint circuits described earlier and, in addition, can economise on transmission capacity by time-sharing the capacity required for a return channel under the control of a selection channel. The synchronisation and timing protocols of this function can be those of the main TDMA system.

SUMMARY

The requirement for the multi-service transponder of ECS is to provide data channels for the following rates: 64, 128, 256 and 1920 kbit/s in point-to-point and point-to-multipoint mode. Simple earth stations are needed to minimise the earth segment cost. It has been found that an SCPC FDMA system is a suitable solution as it provides reasonably high capacity by the use of FEC (about 550 64 kbit/s channels) while allowing freedom to modify the channel performance by increasing carrier power level.

A further advantage of the FDMA approach is that different modulation/access techniques can be used on individual frequencies, and the operation of 2 Mbit/s TDMA systems on one or more of the allocated frequencies can be envisaged.

FUTURE TRENDS

It is useful to return to Fig. 4 and compare the operating point achieved today using the multi-service transponder of ECS with the optimum point. Three trends are possible. First, the earth station G/T figure could reduce in order to make satellite multi-services more accessible to the customer by reducing the earth station antenna diameter. Some factors such as improved noise figures obtained from low-noise amplifiers will enhance this trend, but others such as the increasingly important need to protect other satellite systems in the geostationary orbit will make it more difficult to reduce their earth station antenna gain.

The second trend could be for transponder bandwidth to be limited to that which can be supported by the power available. The frequency bands devoted to multi-services may then be used more effectively.

The third trend could be to increase satellite EIRP by increasing satellite amplifier power and by moving to narrower spot beams. This latter trend introduces a loss of connectivity between earth stations working to different beams; this can be alleviated by the use of satellite-switched TDMA (SSTDMA). L-SAT[4] is an example of an experimental satellite which incorporates both SSTDMA and multiple-coverage beams.

The first of these trends produces a movement away from an optimum point, but the other 2 might more than compensate for this and enable future systems to operate in 4-phase PSK where power and bandwidth are both fully utilised.

ACKNOWLEDGEMENT

Acknowledgement is made to the Chief Engineer, British Telecom International, for permission to publish the information contained in this article.

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Digital-Radio Link and MegaStream System for a Large Private-Circuit Network

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Greenhithe is a small town situated in a semi-rural part of south-east England; its small community is served by a 4500 line TXK1 crossbar telephone exchange. The surrounding countryside consists mainly of farmland and chalk quarries, the latter being part of Blue Circle Industries (BCI), which has quarried this area for many years.

In the Autumn of 1981, BCI approached British Telecom London South East (BTLSE) to discuss the possibilities of setting up a network of private circuits which interconnected various BCI sites throughout the country. The main terminal of the network was to be at BCI's Stone Castle site at Greenhithe. After considering various proposals, BCI placed an order in March 1982 for the installation of a large private-circuit switching network working to a GEC SL1 switching node. The proposed network, which involved the provision of 108 private circuits to 25 separate locations around the country, had to be ready for service by September 1982.

Preliminary investigations by BTLSE established that the existing junction capacity between Greenhithe and Dartford and between Greenhithe and Gravesend was not sufficient to carry the additional loading required by this scheme. As additional junction cables could not have been provided within the customer's timescale, BTLSE investigated ways of intercepting and using spare junction plant situated close to the Stonewood repeater station, a few kilometres south of the customer's site. The provision of a duct route between the customer's site and the repeater station would have been costly and would have involved the crossing of a busy trunk road. An overhead route was not considered viable because of the required security of the system.

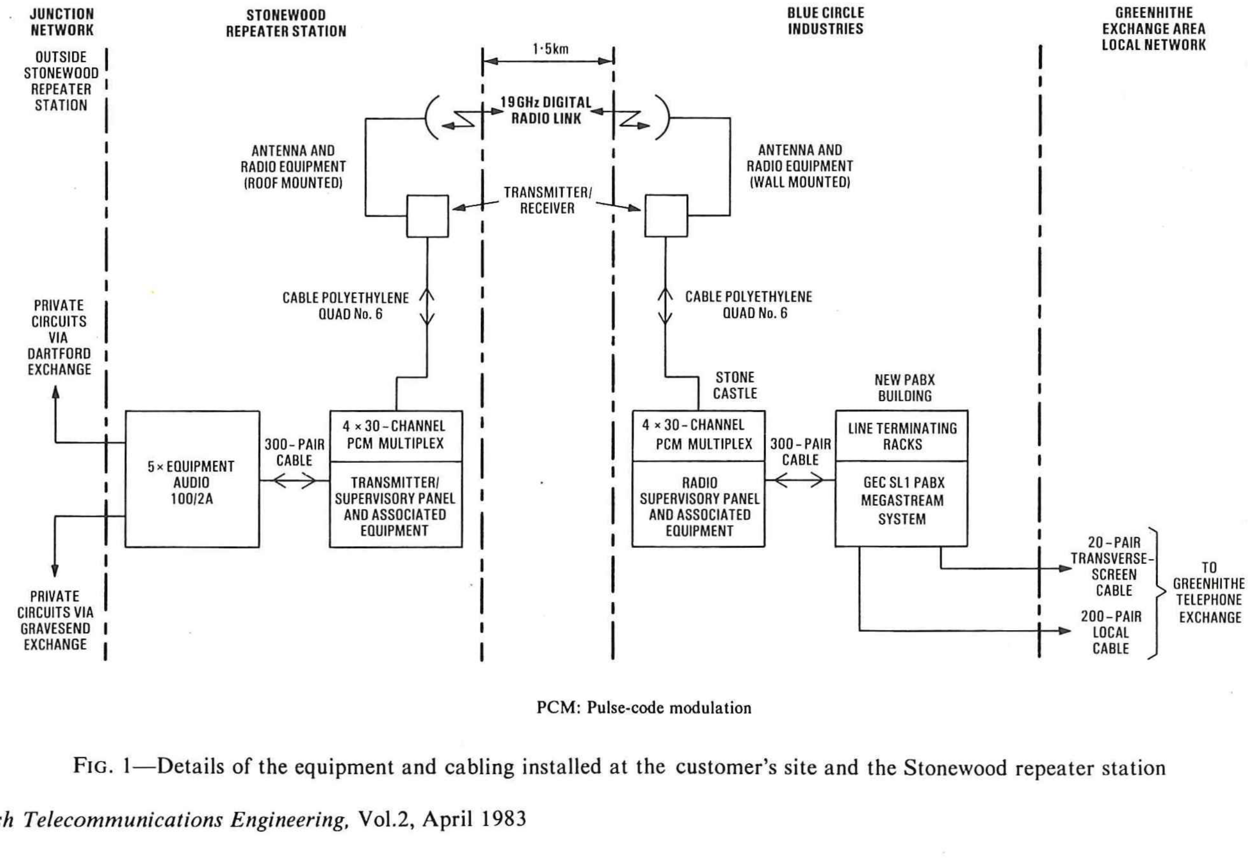
Another possibility was to provide a temporary 19 GHz digital radio system between the 2 locations. The necessary radio and signalling equipment was readily available from British Telecom London (BTL). A survey by staff from BTL and BTLSE quickly proved that the link was feasible; by April 1982, planning for the external cables and equipment was well under way.

In early June, the customer extended his requirements to include a MegaStream system. The ready-for-service date for the complete network was deferred to 8 November 1982. It then became necessary to expedite the planning and provision of a 40-pair transverse-screen cable between Greenhithe and Dartford telephone exchanges, and a 20-pair transverse-screen cable between Greenhithe exchange and the customer's site.

From this point every effort was made to plan, install and commission the vast amount of cabling and equipment required. The block diagram shown in Fig. 1 illustrates the equipment and cabling layout at the customer's site and the Stonewood repeater station. Considerable co-ordination was required not only from divisions within BTLSE, but also throughout British Telecom to ensure that the private-circuit network was ready on time.

It was the first time that a 19 GHz digital radio system, a MegaStream system or an SL1 switching node had been installed in BTLSE Area. But, despite the many problems that were encountered, the considerable efforts of all those involved in the project resulted in the complete system being in service on time, and a customer being well satisfied.

† British Telecom London South East



PCM: Pulse-code modulation

FIG. 1—Details of the equipment and cabling installed at the customer's site and the Stonewood repeater station

The Sixth International Conference on Computer Communication: A Review

Part 1—The Plenary Sessions

M. B. WILLIAMS, B.SC.(ENG.), C.ENG., M.I.E.E.

UDC 681.3 : 621.39 : 061.3

This 2-part article reviews the sixth International Conference on Computer Communication, which was held in London from 7–10 September 1982. In this first part, an introduction by the Conference Chairman and a summary of the opening and closing plenary sessions are given. The second part, to be published in a forthcoming issue of the Journal, will review the 4 parallel sessions of the Conference.

INTRODUCTION BY THE CONFERENCE CHAIRMAN

The International Council for Computer Communication (ICCC) has now established itself as the authoritative forum for bringing together a wide spectrum of people working in the rapidly converging fields of computing and communication. British Telecom was host for the sixth International Conference on Computer Communication (ICCC '82) held from 7–10 September 1982 at the Barbican Centre for Arts and Conferences, London, under the patronage of His Royal Highness the Duke of Kent, who opened the Conference.

ICCC '82 was the first major conference to be held at the Barbican Centre since its opening to the public in March 1982. The focus of the Conference was the magnificent new Barbican Hall; with a seating capacity for 2000 it was well suited to the formal opening and closing sessions and to the general sessions of wide appeal.

The theme of ICCC '82 was *Pathways to the Information Society* and it was very fitting that ICCC '82 was held in the UK during the year which had been designated by the British Government as Information Technology Year and, moreover, that the Keynote Address on the Conference Theme could be given by the Minister for Information Technology.

In the initial formulation of the Programme, 3 topic areas within the broad field of computer communication had been identified and papers invited in these areas; namely, service and business aspects, systems technology, and social and human aspects. These 3 areas were introduced by theme speakers invited from distinguished workers in these fields.

Mr. T. A. Larsson, Deputy Director-General of the Swedish Telecommunications Administration, spoke on *Service and Business Aspects*; Dr. I. M. Ross, President of Bell Laboratories, spoke of *Micro-electronics, Software and Communications*, and Mr. F. J. M. Laver, formerly Board Member for Data Processing of the British Post Office, gave a lively but nonetheless thoughtful paper entitled *Computers and Communications and People=?*

Some 350 abstracts of papers were received initially, followed by some 230 draft papers which were considered by the Papers Sub-Committee and an international panel of 115 referees. The quality of the papers, the range of topics and the spread of authorship, both by country and by expertise, justified to the Programme Committee the eventual acceptance of 172 papers from 14 countries for printing in the *Proceedings* (see Table 1).

For presentation at ICCC '82 the papers were arranged in 4 parallel streams, as shown in Table 2. Two sessions, on *transborder data flow* and on *regulation and public policy*, were arranged as panel discussions with experts to lead the discussion. In the final plenary session of the Conference, 2 closing papers were presented as valedictory messages. Dr. D. M. Leakey, GEC Telecommunications Ltd., spoke on the theme of *Possible Trends in Computer Communication* and Dr. S. Winkler, past-President of ICCC, reflected on the implications of the past 10 years' developments and the prospects for the future in an address entitled *The Quiet Revolution Revisited.*

The now traditional Flag Ceremony brought ICCC '82 to a close, with thanks to all who had contributed to the success of ICCC '82. After reminding delegates that ICCC '84 would be held in Sydney, Australia (joint hosts being the Overseas Telecommunications Commission and Telecom Australia) I handed the ICCC flag for safe keeping to the Chairman-designate, Mr. J. Curtis.

Viewed from the chair, ICCC '82 was a memorable event. The fact that over 1600 participants from 37 countries and a wide range of disciplines (see Table 3) had come to attend the largest ever conference in the series, the opportunities to renew old friendships and to make new ones, and not least the highlight of the social programme when 700 delegates and guests dined together in London's 1000 years old Guildhall, all served to demonstrate the importance and vitality of our profession.

J. S. WHYTE, C.B.E.
Managing Director (Major Systems)
and Engineer-in-Chief, British Telecom

Flag Ceremony at the close of ICCC '82. Mr. J. S. Whyte hands the ICCC flag to Mr. J. R. R. Cook for ICCC '84.

TABLE 1
ICCC '82 Papers

Country	Final Papers Received
Australia	3
Canada	14
Finland	1
France	6
Germany FGR	18
India	1
Israel	2
Italy	9
Japan	11
Sweden	2
Switzerland	3
Taiwan	1
United Kingdom	58
USA	44

TABLE 3
Registrations by Affiliation
(Excluding Press and Unclassified)

Telecommunications Operating Organisations	419
Users and Government Departments	302
Telecommunications Industry	264
Computer Industry	250
Universities and Research Institutes	209
Consultants, Computing Services	128

TABLE 2
Arrangement of Sessions for ICCC '82

Stream A	Stream B	Stream C	Stream D
ISDN—planning and implementation ISDN—systems definition	Office systems—strategy Office systems—standards and systems	Human factors—man–machine interfaces Regulation and public policy	Distributed systems—architecture and organisation Open systems interconnection I
Public data networks—services Public data networks—systems Local networks—architecture and standards The Bell System packet transport network	Satellite systems—definition and facilities Teletex services Office systems—the PABX approach	Human factors—the friendly system Applications in education Information network architecture	Switch architecture Distributed systems—implementation Open systems interconnection II The UNIVERSE project
Local networks—implementation and experience Intelligent network services I Intelligent network services II Videotex	Teletex—usage and users Satellite systems—integrated networks Local radio networks Applications in banking and electronic funds transfer	Human factors—office systems Transborder dataflow—legal and economic considerations Pricing and allocation in communications networks Applications in medical services	Protocols—low level Protocols—high level Protocol proving and validation Routeing and flow control
Local networks—access protocols Public data networks—operational aspects	Optical systems I Optical systems II	Transmission technology Network management	Network interconnection Network performance

ISDN: Integrated services digital network   PABX: Private automatic branch exchange

THE PLENARY SESSIONS

OPENING PLENARY SESSION

The Conference Chairman, Mr. J. S. Whyte, Managing Director (Major Systems) and Engineer-in-Chief, British Telecom (BT), welcomed delegates to ICCC '82 and indicated that the ICCC Flag, the symbol of continuity, had been passed on from ICCC '80, held in Atlanta, and now marked the first ICCC Conference to be held in the UK.

He went on to say that delegates to ICCC '82 would be honoured and delighted that a member of the Royal Family was the Conference Patron. His Royal Highness the Duke of Kent played an active role in the industrial and technical life of the UK. Among many other offices that he held he was the President of the Royal Institution and the Chairman of the National Electronics Council, but particularly and most significant to ICCC he was the President-Elect of the British Computer Society. Despite the very many other calls on his time he had agreed to assist ICCC '82. The Chairman then invited His Royal Highness the Duke of Kent to open the Conference.

Opening Address

The Duke of Kent delivered the following address:

'Mr. Chairman, Ladies and Gentlemen, I feel enormously privileged and honoured to have been asked as Patron, to open this important event, the sixth International Conference on Computer Communication and to be addressing such a highly distinguished audience of delegates from all over the World.

It is both very pleasing for us and I think most appropriate that in 1982 it should be Britain's turn to act as hosts for the Conference because this year has been designated Information Technology Year by the British Government, and I have no doubt the Minister of State, Mr. Kenneth Baker, will be referring to this when he speaks to you shortly. But there are other reasons too why Britain is proud to welcome you all here. For it was the Englishman, Charles Babbage, who actually invented the computer—it was not of course electronic and he called it the *analytical engine*—in the early nineteenth century. It was also by our countrymen that pulse-code modulation, the basis of modern digital transmission systems, was invented (in 1938) and the use of geostationary satellites for global telecommunications was first proposed. So that our national links with the 2 main disciplines that come together in the ICCC are very strong.

I am impressed too by the wholly international character of the ICCC, which is very evident in the world-wide span of its Governors and its Executive, in the rotation of its venue around 3 Continents, and most especially in the composition of this audience, whose delegates I know are drawn from many different countries.

At the opening of the sixth of this series of conferences, sponsored by the International Council for Computer Communication it is natural to reflect on the 10 years that have elapsed since the first one was held in Washington in 1972. These years have witnessed the veritable transformation of computing thanks to the extraordinarily rapid development of micro-electronic circuits from an eclectic and rather specialised discipline to the point where its ramifications are universal and it has become the hobby of everyman.

Telecommunications over the same period have evolved with comparable speed, having embraced the computer as their servant and developed specialised networks to serve it.

These twin technologies continue to forge ahead at an unrelenting pace and delegates at this conference have the challenging task of managing and guiding their development for the future.

You have during these 4 days, a very full programme of papers, covering a huge range of topics, many of them highly specialised. Two thoughts have particularly struck me from a brief study of the list of papers being presented. There is first the very extensive participation by public telecommunications organisations and by the world-wide computer industry, which indicates that the topics under discussion are of very vital and immediate concern; and the second point is the ever present and increasingly important topic of standards. Standards and telecommunications have traditionally gone hand in hand, and for over 100 years the International Telecommunications Union has served to co-ordinate the evolution of national and international systems. The computer industry, by contrast, has not had the same motives for standardisation and in consequence has not yet evolved a comparable system of standards. I believe that one of the most important features of the ICCC Conferences may be the cross-fertilisation between the 2 industries and the impetus that the long years of telecommunications development can give to formulating and implementing standards for computer communication.

Another feature of the programme, which I particularly welcome, is the emphasis which ICCC places, quite rightly, on the practical use of the new technologies and the attention given to their social and economic effects. This aspect is of particular interest to me as Chairman of the National Electronics Council whose role it is to draw attention to all facets of electronics in relation to the national life. So I note with interest that there are to be sessions on human factors as well as applications to education, finance and medical services. It is, in the end, the impact which these great technical developments make on our everyday world, the effect they have on the way human beings live and the quality of their lives which is of primary importance; and this, in my view, is the one central factor which needs to be borne in mind through all these complex presentations and discussions.

I am sure that delegates to this conference will not need to be reminded that electronics, as expressed through the twin technologies with which you are chiefly concerned, exists solely to serve the interests of mankind.

I am delighted to observe that your programme gives you opportunities, in between the serious business of the conference, for sightseeing and visits to historic places as well as for social events.

It has been suggested that these activities are almost as important as the main sessions of the conference itself and certainly many good contacts can be made and much valuable business transacted during these informal moments.

I now wish you all an extremely enjoyable and successful Conference and I have pleasure in declaring open ICCC '82'

Keynote Address

Introducing the keynote speaker, Mr. Kenneth Baker, the Conference Chairman paid tribute to the personal contribution and zeal which he had brought to the subject and to his unique position as the Minister for Information Technology in the British Government.

Speaking about the Conference Theme, *Pathways to the Information Society*, Mr. Baker described the development and application of micro-technology as already providing the main motive force for economic development in the world; world trade in information technology products was expected to rise from £54×10^9 in 1980 to £105×10^9 in 1985. At a growth rate of 14% per annum, this was unmatched by any other industry. He reviewed government plans for taking advantage of the potential of the new technologies. These plans involved some £170M support in 1983:

(*a*) at the basic level in the design and manufacture of specialised devices and in the study of new computer architectures;

(*b*) at the users' and applications levels in sponsoring integrated office systems and integrated manufacturing systems (with local networks, office machinery, computer-aided design and numerically-controlled machines); and

(*c*) at the national level in promoting competition for the supply and financing of public telecommunications services.

He also drew attention to the government's interest in cable television, as indicated by the setting up of the Committee under Lord Hunt, and by its interest in communications satellites.

Mr. Baker concluded by noting the Conference sessions on human factors. He saw these as particularly significant

as the proportion of the work-force employed on information-related activities increased from the present 40% to some 50% within the next few years. As a consequence of this trend the government was well launched on a programme to introduce computers into schools and training centres.

He believed that the world was further down the Pathway to the Information Society than was generally realised and he looked forward to international co-operation in the full and free flow of information and to future joint international ventures in the high technologies.

Presidential Address

As an overture to the technical sessions that formed the principal content of ICCC '82, the opening plenary session concluded with 3 addresses given by distinguished speakers. This part of the Conference was to have been introduced by an address by the President of the ICCC, Douglas Parkhill, Unfortunately, urgent hospital treatment had prevented his attending ICCC '82 and his address was given by the Executive Vice-President, Professor Philip Enslow, Jnr. In his address the President had noted the appropriateness of Great Britain as the venue for celebrating Information Technology Year mentioning the individual contributions of Charles Babbage and Alan Turing and the teams at Cambridge and Manchester universities and the National Physical Laboratory.

However, he saw the information revolution as a worldwide phenomenon that would affect nearly all facets of life on earth; its significance was being recognised by world leaders.

He considered that combining information with communications was a challenge for the developed countries that were now ready to move beyond the industrial age. They should do so without leaving behind the developing countries who had yet to complete their own industrialisations.

Theme Addresses

Micro-electronics, Software and Communications

The first of the theme addresses, entitled *Micro-electronics, Software and Communications*, was delivered by Dr. I. M. Ross, President of Bell Laboratories, USA. He discussed aspects of these technologies that were shaping the Information Society. The past growth of silicon integrated circuits, which now account for up to 40% of the hardware costs of current switching systems, would continue and 4 Mbit memory chips would be possible by the late 1980s; sub-micron metal-oxide semiconductor circuits with picoseconds logic switching were already possible. He thought that future progress would lie in the replication and interconnection of many small processors and, therefore, that new system architectures should be considered.

Dr. Ross then reviewed the problems posed by the complexity of the software of large systems. This was often the result of making the users' interface simple and the system extremely reliable. Typical Bell System switching machines with around 1 million lines of code achieved down-times of 0·001%. He thought that software design problems should be minimised by keeping to small projects wherever possible.

Dr. Ross concluded his review of technologies with a survey of the possibilities for *photonics* in which he referred to the successful exploitation of optical fibres as a replacement for cables (24 100 km of fibre installed as inter-Central Office links in the Bell System during 1981) and as an internal bus for switching machines (30 Mbit/s in ESS No. 5). Future developments of optical systems will extend to undersea links as well as broadband video service to end users. Although photonics could embrace optical logic and could generate the shortest known pulses (30×10^{-15} s pulses had been generated), high powers and relatively large dimensions, which could not compete with silicon logic, were involved.

In conclusion, Dr. Ross warned that the economic and social progress offered by the Information Age depended on the technical systems being reliable and universally acceptable to the people who use them.

Service and Business Aspects of Computer Communications

The second theme address, *Service and Business Aspects of Computer Communications*, was given by Mr. T. A. Larsson, Deputy Director-General and Head of the Technical Department of the Swedish Telecommunications Administration.

He began by noting the economic position in Sweden where both the gross national product (GNP) and the proportion of GNP represented by telecommunications were increasing. By the year 2000, telecommunications might require 2·7% of a substantially expanded economy, indicative of a move towards a service-oriented society.

The Nordic countries recognised some years ago the importance of data communications to the development of distributed data processing, and decided that problems of incompatibility and cost efficiency could be minimised by providing a public data network conforming to CCITT† standards. This network operates mainly by circuit-switching techniques, but includes a small packet-switched network. Future developments of the public data services are planned to include the following features:

(*a*) a more extensive packet-switched network;

(*b*) a satellite network for high-speed point-to-point communication;

(*c*) a 64 kbit/s digital service based on a modernised public switched telephone network;

(*d*) a possible integrated services digital network (ISDN), depending upon CCITT standards, perhaps by 1990;

(*e*) digital PABXs with data communication, Telex and Teletex compatibility;

(*f*) Teletex, Telefax*, videotex, mailbox and electronic-funds-transfer services.

In conclusion, Mr. Larsson considered the short-term problems caused by the incompatibility of different types of network and the variety of terminals that customers will need to interconnect. An intelligent network, providing a full range of conversion facilities, might be feasible. Even if such a network were utopian, conversion problems could be eased by the full development and adoption of standard protocols according to the open systems interconnection model now being studied by the ISO††.

Computers and Communications and People = ?

The third theme speaker was Mr. F. J. M. Laver, formerly Board Member for Data Processing in the British Post Office. Since his retirement he had expressed a keen interest, through writing and lecturing, in probing the social and human consequences of technology. He is Pro-Chancellor of the University of Exeter. Mr. Laver's address, with the provocative title *Computers and Communications and People=?*, was aimed at reviewing the social consequences of computer communications. He began by pointing out the following difficulties in predicting such consequences.

(*a*) Economics and sociology were themselves difficult subjects and our understanding of them was only rudimentary.

(*b*) Technology was changing very rapidly.

(*c*) Technology was changing the circumstances within which predictions were being made.

(*d*) The consequences included unplanned side-effects. These were uncontrolled to the extent that information

† CCITT—International Telegraph and Telephone Consultative Committee

* A tele-facsimile service

†† ISO—International Organization for Standarization

technology was being promoted and introduced for reasons that were neither related to social consequences nor subjected to the scrutiny of social scientists.

Developing this last point, Mr. Laver pointed out the relative novelty of examining the social consequences of new ventures, and warned against regarding such an examination as totally separate from the technical study itself. He deplored the intellectual parochialism which followed excessive specialisation of hardware and software designers and which allowed them to abrogate responsibilities for the social consequences of their work. He saw dangers in a similar narrowness of view that did not envisage the different impacts and reactions which information technology would have on various identifiable groupings within society.

Returning to his main theme—predicting the consequences of computer communication—Mr. Laver wondered what aims and objectives should be set if such predictions proved to be possible. He hoped these would not be solely market-orientated, but would deliberately set out to adapt machines to human society. He gave examples of several identifiable groups in society who had an interest in social consequences, and he warned that the present time had no particular significance for such discussions since it was likely that the major, and most rapid changes, were yet to come.

In conclusion, Mr. Laver put computer communication and information technology in perspective as the technical means to achieving much broader ends. Discussion of social consequences should be in the broader context within which the development of information technology was being motivated.

CLOSING PLENARY SESSIONS

At the conclusion of the parallel sessions of ICCC '82 a plenary session was held during which valedictory addresses were given. The first of these valedictory addresses was given by Dr. D. M. Leakey, Technical Director of GEC Telecommunications Limited. In his address, *Possible Trends in Computer Communications*, Dr. Leakey covered the following topics:

(*a*) possible technological innovations,
(*b*) possible user requirements, and
(*c*) commercial pressures and their possible effect on future communications systems.

Dr. Leakey saw that reconciling the rapidly growing complexity of integrated circuits with practical problems of manufacturing yield and testing would require a new design approach, which would accept a reasonable probability of correct operation rather than precise operation.

Users' needs would be better matched if terminals could make use of a range of human attributes such as the ability to extract information by rapid scanning as well as by pattern matching, to construct and read hand-written messages and to use speech input and output.

The implications of these users' needs on communication systems could be profound; for example, variable rate channels with self-optimisation, and coding of information in ways that reflect the significance of the data or of any errors that were introduced.

The final formal address in ICCC '82 was given by Dr. S. Winkler, past President of the ICCC and Conference Governor. In his address, *The Quiet Revolution Revisited*, Dr. Winkler looked back a decade to ICCC '72, the first of the biennial conferences sponsored by the ICCC.

This quiet revolution was the changing way of life which computer communication was promoting; he was confident that the revolution was continuing and that it would be beneficial despite concern over social impacts from the interaction between technology and society.

The revolution fostered by computer communications was foreseen by Douglas Parkhill as long ago as 1966. It began with the demonstration of ARPANET at ICCC '72 and its progress was marked by the maturing of public data networks, the concept of the office of the future, the emergence of local networks and the proliferation of personal computers. Distributed computing had expanded to include intelligent terminals with data networks and would soon be joined by intelligent robots.

Platform party at the closing session of ICCC '82. From left to right are Dr. S. Winkler, Dr. P. Jackson, Mr. J. S. Whyte, and Mr. J. R. R. Cook.

The effects of these developments on life, travel and work had not yet fully unfolded. Certainly, much work has changed in high-technology manufacturing processes, automated warehousing and production lines and office systems. However, neither travel itself nor the need for workers to travel to and from the workplace has changed as a direct result of computer communication. The personal computer at home and in education was laying the foundation for significant changes when future communications facilities would be added.

In conclusion, first expressing doubts that separation of home and workplace would ever cease, Dr. Winkler foresaw the explosive impact of computer communication on the dissemination and replication of ideas. He believed that good ideas would triumph over bad so that the best features of the Quiet Revolution were yet to come.

CLOSING CEREMONY

The Conference Chairman then invited Dr. P. Jackson, past-President of the ICCC, to address the conference on behalf of the President. Dr. Jackson spoke of the initial discussions in 1976 with the UK governors of the ICCC regarding a London conference and expressed his pleasure that ICCC '82 had been held in London and was 'the very best so far'. He acknowledged the substantial resources expended by BT as the host organisation, and emphasised that ICCC Conferences are not run at a profit. So far as the balance of the meeting was concerned, he noted the multidisciplinary aims of the ICCC, which were concerned with the applications and impacts of technology as well as the technology itself. ICCC '82 had struck an excellent balance.

In closing the Conference, the Chairman acknowledged the contributions, authors and all who worked to make ICCC '82 a success. He looked forward to ICCC '84 and invited the designated Conference Chairman, Mr. J. R. R. Curtis, to welcome delegates to Sydney, Australia. Mr. Cook reviewed the arrangements for ICCC '84, which is to be held in the Sydney Opera House from 30 October–2 November 1984, with Telecom Australia and OTC Australia as hosts and with the support of the Australian Computer Society and the endorsement of the Federal and State Governments. All the committees for ICCC '84 were active and the *call for papers* had been distributed.

To be continued

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TXE4 Configuration Control

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This article briefly describes a new co-ordinated control system for the TXE4 exchange system. Attention is concentrated on the benefits and new facilities that it will bring to BT. The details of compatibility control's activities also provide a useful insight into the possibilities for rapid development, with minimum manpower, when modern technology is appropriately utilised.

INTRODUCTION

The TXE4 electronic exchange system[1,2] has been in service with British Telecom (BT) since 1976, when the first exchange was brought into service at Birmingham Rectory. As with all switching systems, continued development has taken place and the original design (known as *TXE4 RD*) has now evolved to a new version known as *TXE4A*[3,4]

TXE4 Configuration Control has been set up by BT's Inland Division Headquarters (IDHQ) to co-ordinate the many interrelated activities necessary to implement changes to the TXE4 system.

GENERAL

Certain aspects of TXE4 documentation are closely linked with Configuration Control and these are described briefly below.

Exchange Master Lists

When exchange equipment is ordered either on a stores order or on a supply-and-install contract works order, the minimum issue level of the equipment to be supplied is quoted as a given issue of appropriate exchange master list(s) (EMLs) plus specific addenda. The EML specifies the issue of equipment down to a very detailed level in the documentation of each system. It is also important to remember that the conditions for a TXE4 contract works order quote more than one EML, because the equipment used is not all part of the TXE4 system; for example the distribution frames and traffic recorders.

Product Change Status and Control Sheet Issue

TXE4 equipment can largely be described in terms of its racks and slide-in units (SIUs). Any particular rack or SIU has product change status (PCS) and control sheet issue (CSI) details which describe its current state. Often the CSI is higher than the equivalent PCS because the CSI changes for every change to the equipment (even if it is just editorial in the documentation) while the PCS alters only when there is a significant hardware or software change to the relevant equipment. TXE4 SIUs contain printed-wiring boards (PWBs) and the layout of these PWBs changes during the evolution of a particular piece of equipment. For example, one or more changes may be implemented into manufacture by cut-and-strap operations on one layout of PWB, but eventually a new PWB layout would be introduced into manufacturing to save production costs. In simple terms, the description of an equipment state in the PCS, the CSI and the PWB issue (termed *etch* on TXE4A equipment) defines the build level.

TXE4 Change System

For the purposes of this article, it can be assumed that each change to TXE4 equipment is detailed in a change note*. Each change note may affect a number of different types of SIUs and racks, and must be implemented in one operation. Some change notes can be carried out only after other change notes have been implemented (either for compatibility or for operational reasons). If an error is found in an issued change note, it is corrected by issuing another separate change note. In such cases, the later change note refers back to the earlier one, but not *vice-versa*.

One section of a change note includes the technical detail of the change for direct labour (DL) modification of equipment (often in an in-service exchange). The final working instructions issued to Regional Headquarters are known as works specifications. Usually each works specification implements one change note. Telephone Area Headquarters implement works specifications in an order and timescale that suit local circumstances; thus the PCS of equipments in a practical exchange do not advance in accordance with either the issue of works specifications or the progress of the theoretical design level of the exchange system.

TXE4 Equipment Practice

Configuration control of TXE4 is made more complex because:

(*a*) a function covered by a particular document is often distributed over several different SIU and these, in turn, may be distributed over several different types of rack,

(*b*) any particular SIU may well contain parts of several functions, and

(*c*) TXE4 equipment is ordered in terms of an item library file (ILF) code. Each ILF code may specify more than one type of SIU and more than one of any particular SIU type. In addition, a particular type of SIU may be ordered as part of several different ILF codes.

The following features of the above systems are important to note for the purposes of this article.

(*a*) Although the manufactured PWB issue of a piece of equipment at any particular time is fixed for any one manufacturer, it may not be the same for all 3 manufacturers of TXE4 equipment.

(*b*) All PWB issues ever made will continue to exist in working exchanges, and the details of any subsequent modification may well be different for different etches of the relevant PWB.

(*c*) To describe the state of a piece of TXE4 equipment it is not adequate to quote just the highest PCS that applies; negative PCS (that is, ones that have not been implemented) can exist for a number of reasons:

(*i*) certain PCS may apply only to certain etches of the PWB,

(*ii*) unlike most other exchange systems operated by BT, non-retrospective modifications do not result in a new identity for the equipment, but are merely another PCS level, and

(*iii*) changes do not necessarily have to be implemented in strict PCS order, it all depends on the compatibility conditions.

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* In the past, the change notes were designated with prefixes such as A, POD or POH, but in the future will use only POH. In practice, a change is usually detailed in a related series of change notes known as the *splash* and *ripples*.

(*d*) Equipments with common PCS should be electrically equivalent, irrespective of the etch of the PWB. Human error will occur, however, and in some circumstances a modification of the new PWB may be needed for equivalence to the existing PWB (or even for the new PWB to be operationally usable at all). In such cases, the PCS of the equipment which uses the etches of PWB will be equivalent to equipment with a PCS one higher if that uses the new PWB.

HISTORY

When Standard Telephones and Cables plc (STC) were the design authority for the TXE4 system, they controlled and monitored the evolution of this exchange system from a single group known as *Configuration Control*. This group had the responsibility for the identification of all compatible combinations of equipment PCS levels. In addition, it had responsibilities for controlling the build level of manufactured equipment and the final PCS level of equipment supplied on specific STC contract works orders.

In the autumn of 1981, BT had been the design authority for TXE4 RD for some time, and the transfer of the TXE4A version to BT control was imminent. It was decided that the existing procedures for co-ordination and control of changes to TXE4 RD, both within BT and between BT and the manufacturers, had proved to be inadequate and that a revision was necessary. A new procedure has been introduced to cover all TXE4 equipment and has assumed the STC title of Configuration Control.

CONFIGURATION CONTROL IN GENERAL

It is important to remember that Configuration Control does not introduce any new tasks, but merely pulls together under one scheme many existing interrelated activities. To illustrate this point, the following tasks, which may be required when there is a design change to the exchange system, are covered within the new procedure:

(*a*) agreement to the technical detail of change notes,

(*b*) publication of DL instructions for BT execution of changes (works specifications),

(*c*) agreement with the manufacturers to the implementation of changes on contract works orders,

(*d*) alteration of TXE4 dimensioning rules (for traffic dependent items),

(*e*) alteration of equipment specification standards for exchange works—for traffic or non-traffic dependent items on contract or DL works,

(*f*) provision of new or amended exchange name documentation,

(*g*) update of the appropriate EML (or equivalent), and

(*h*) arrangements for distribution of the system documentation altered or created as a result of a change.

By the explicit recognition of the links between these activities, the probability of satisfactory co-ordination is immediately increased. The opportunity has, however, naturally been taken to improve each individual activity where possible. Where appropriate, these improvements are described in this article.

The TXE4 Configuration Control procedures do not cover the non-TXE4 equipment that is used in TXE4 exchanges.

Aims

There are 4 basic aims for the new TXE4 Configuration Control procedure:

(*a*) to create mechanisms whereby the introduction of TXE4 system changes can be accomplished as efficiently and smoothly as possible,

(*b*) to include explicitly, within the procedures agreed with the manufacturers, the necessary direct engineering consultations between BT and the manufacturers on TXE4 equipment changes,

(*c*) to improve the co-ordination between the various BT activities which can be necessary to implement a change, and

(*d*) to review the methods used to distribute the necessary information on TXE4 configuration both within IDHQ and to the Regions and Areas.

Responsibilities

The BT responsibilities under TXE4 configuration control are split between various groups in IDHQ (for Change Control and Compatibility Control), and the Regions/Boards as described below. These responsibilities do not include any manufacturing aspects.

Responsibility for TXE4 Change Control is divided between the local exchange DL group for cabling and the development groups for the remaining TXE4 equipment. TXE4 Change Control has authority for the design and documentation of the system. They are also responsible for the identification of all compatible combinations of equipment PCS levels; this, in consequence, defines combinations of equipments that are incompatible. Although the new procedure establishes new methods of working for TXE4 Change Control, their basic responsibilities remain unchanged.

The TXE4 and common equipment specification standards group in IDHQ is responsible for Compatibility Control. The functions of Compatibility Control are to co-ordinate all planning activities in IDHQ that are consequent upon TXE4 system changes, to arrange for timely implementation of system changes by the manufacturers, and to provide IDHQ and Regions/Boards with concise configuration information. Inclusion of changes into the EML or equivalent will be triggered by Compatibility Control when agreement on implementation has been reached.

Regions/Boards are responsible for the configuration of individual exchanges. When a contract works order is placed, the manufacturer concerned accepts a liability to supply equipment to minimum issue levels (as quoted for example in given EML plus stated addenda) or higher. There is a contractual obligation on the manufacturers to gain BT's agreement if an earlier version of the equipment is to be supplied, and to inform BT when the later equipment is to be supplied. It is the responsibility of Regions/Boards to ensure that existing exchange equipment is compatible with that to be supplied on an extension. For contract extensions, it is possible that the manufacturers will supply details of the modifications that BT must necessarily complete to ensure compatibility. But for DL works, whether the equipment is from a stores order or TXE4 equipment re-use, BT must have the ability to make similar judgements. In addition, Regions/Boards need to be aware of those changes that are needed to raise the effective design level of any particular exchange; for example, to gain a new facility.

From the Regional viewpoint, the functions of TXE4 Change Control and Regions/Boards are unchanged by the introduction of the TXE4 Configuration Control procedures. Compatibility Control is however a new concept and, to be successful, will need to have a direct impact on the working methods of Regional/Board staff responsible for TXE4 exchanges.

Timescale

BT became the design authority for TXE4A in March 1982. In the autumn of 1982, BT placed a contract with STC for them to continue with certain aspects of Configuration Control until the end of March 1983. This included the provision of a few copies of STC computer print-outs of historical system change information for the use of BT and the other manufacturers. Unfortunately, it was not possible or desirable to reproduce and distribute copies of this information because of its bulk.

Initially, the BT TXE4 Project Control was responsible for the implementation of changes for all equipment used in TXE4A exchanges (including inter-working equipment). Compatibility Control assumed their responsibilities for TXE4 RD equipment, in December 1982, when the new Configuration Control procedures for change control were implemented.

Exacting objectives were set for the creation of an effective Compatibility Control. Staff were allocated in April 1982 and given one year to produce all necessary procedures and instructions. With one exception, the staff who created Compatibility Control had no significant computing experience or training prior to this project.

COMPATIBILITY CONTROL

A review of the way in which Compatibility Control was created reflects the concern for minimising staff requirements and achieving the rapid set-up necessary to obtain a reasonable return. With limited staff resources, this was possible only by the maximum use of the latest techniques of data storage and information processing.

Often during the development of the detailed procedures there was a need to decide whether to expend effort and incur complexity in Compatibility Control or to leave the users throughout BT each to solve the problems themselves. To achieve the most efficient overall scheme, priority was given to simplicity and ease of application for the user.

Documentation Packages

To ease the DL and contract implementation of system changes, some new distribution arrangements have been made for system documents. The old procedure required BT staff to requisition separately each document required for a works specification which, therefore, required separate processing by BT Reprographics Service's (RS's) distribution duty. Manufacturers received their documents as a package only because of special action by the design group; an action that would have ceased with a recent reorganisation. Yet delays to the implementation of changes into manufacture and the consequential extra cost to BT would have been inevitable if documents were not sent as complete packages.

The new scheme provides for all documents that are produced or amended as a result of a change to be issued as a single package for works specification implementation and for use by manufacturers. A package comprises one copy of each document altered as a result of a specific change. Packages are designated by the 4-digit number of the relevant change note for ease of identification. The availability of packages is made known within BT in the same way as individual document availability has been notified for many years (that is, the *Fortnightly Schedule*), so that the existing Regional and Area monitoring procedures did not need to be changed. Package availability dates are also included on the TXE4 compatibility database (CDB), details of which are given later in this article.

The assembly and postage of packages to manufacturers and the BT RS distribution duty is carried out and monitored by Compatibility Control. This arrangement ensures that distribution is co-ordinated with negotiations on implementation and enables the identification (for clearance) of documentation delays. In addition to the silver halide microfilm masters for the documents, which make up the packages for internal distribution, the packages distributed to the manufacturers may also contain artwork masters (for the production of PWBs) and magnetic tapes (for example, for automatic rack wiring). The storage and packing of such mixed packages also posed some interesting problems.

Document masters are passed from the Change Control to BT RS, via the drawing office, on an individual document basis. Microfilms and other documents appropriate to an individual package are therefore received by Compatibility Control in an order that is not related to the specific changes covered. It is important to be able to identify when all documents for a specific change have been received, when there has been too long a delay after release of the final change note before a single document is received, and when particular documents within a package have taken too long to arrive. By storing all appropriate records on a standard small business computer (SBC), all necessary sorts and searches can be carried out with the minimum of effort. In addition, the SBC is used to produce the standard letters required to accompany the document packages to the manufacturers and to the BT RS distribution duty. These letters include the list of documents contained in each package, the details being added automatically using standard software packages.

Co-ordination

Compatibility Control is responsible for ensuring that BT staff, who need to produce or revise guidance because of a change, are sufficiently aware of the detail and timescale. The activities which it is hoped to co-ordinate in this way are the provision of any necessary planning, specification, exchange name documentation, allocation, and works specification information. In particular, compatibility control is responsible for ensuring, at the draft stage, that change notes are appropriately structured to ease agreement of implementation with the manufacturers.

Record of Equipment Supplied

The record of equipment supplied is a document supplied by the manufacturers to BT which uniquely identifies the issue of the equipments supplied on extensions or stores orders.

There has always been an obligation on the manufacturers to provide a record of equipment supplied on their contracts for TXE4 equipment (either contract extensions or stores orders), and clearly these records are an important input to any Regional/Area records. In the past, confusion has arisen because of the different content and presentation of the records produced by the 3 manufacturers. There has also been confusion because the manufacturers often call the record a *shipping list*, a term which to BT signifies only the note that accompanies equipment when it leaves the factory. In addition, the contractual details were only published in the overall contracts with the manufacturers and are only readily accessible to a very limited number of people within BT.

The records, as produced in accordance with the current TXE4 system contracts, are largely geared to an inventory control scheme which was never introduced. They have 3 main drawbacks for the current requirements of BT:

(*a*) they are not amendable,

(*b*) they are voluminous, with one or more line per equipment serial number (rather than the broader classification of equipment type), and

(*c*) they do not give details of the relevant PWB issue.

Two of the 3 manufacturers prepare their record of equipment supplied from computer systems, and, at this stage of the ordering programme for TXE4, it was not considered economically justified for BT to sponsor a change to the content or format of the lists prepared in this way.

To ensure that Regions can make the best use of the records of equipment supplied, Compatibility Control has issued guidance to Regions and Areas on the obligations of the manufacturers and on the interpretation of the records. This guidance includes charts to convert manufacturers' own codes to etch for TXE4A equipment. It has also been confirmed that those Regions that wish to use the records as a basis for amendable exchange records are not inconvenienced in those cases where equipment details are given on equipment serial numbers rather than just equipment types. In order to maintain the records they must be in an

amendable form, and this can be accomplished only by transferring the information either to exchange name documentation type forms or to files on SBCs etc.

TXE4 COMPATIBILITY DATABASE

Title

The term TXE4 compatibility database was chosen because its control is the responsibility of TXE4 Compatibility Control. The 10 Mbytes of data in the CDB do, however, represent a good deal more than just compatibility information.

Basis and Contents

Information on TXE4 changes and ordering codes was originally available in system documents, works specifications, BT Specifications TE22000 and TE24000 (which list works specification details in equipment code order), BT Specification TE9500 (which gives the equipment details for all TXE4 ordering codes), and change notes, etc. This was thought to be too distributed to allow effective configuration control. In addition, the production processes involved in publishing new or amended eye-readable information take considerable time and effort. It was not considered adequate for information on works specifications (in the TE22000 and 24000 series) and ordering codes (in TE9500) to be updated as infrequently as say once per year.

Compatibility Control, therefore, created the CDB to provide concise information for the use of themselves, Regions/Boards, Areas and manufacturers. The CDB contains all essential detail on change notes, works specifications, ordering codes and system configuration (mainly in terms of racks and SIUs).

The usefulness of the CDB should not be measured against its likely uses for controlling the information on large numbers of further changes, although it will naturally be of great assistance in processing any changes that do occur. The situation which it addresses is the control for many years of the TXE4 exchanges which are already in service and those which have been ordered, but are not yet in service. The task of controlling the configuration of these exchanges will not be simple because, in the past, there has been a great deal of change to the TXE4 system.

BT resources were not available for Compatibility Control until April 1982. It was therefore essential, for the CDB to have a reasonable useful life, to minimise the effort needed to supply the necessary information. The solution chosen was to set up a RAMIS database system on the BT IBM computer at Harmondsworth Computer Centre. RAMIS is a system that is widely used within BT and easily learnt. The CDB is small in database terms, but it is very complex because of the TXE4 documentation system. Although this posed problems, a workable system was produced using almost exclusively RAMIS. Some use was made of IBM system facilities to provide the HELP system described below. The need to use PL/I programs for future requirements is, however, still a possibility.

As already mentioned, STC had many years experience of running configuration control for both TXE4 and for various other exchange systems. They provided a variety of different computer outputs to BT and the other manufacturers from their own computer database. It was not possible or desirable for Compatibility Control to run the same system because of incompatibilities between the computer hardware and software used by the 2 organisations, and the obvious different requirements to be met. Every effort was however made by Compatibility Control to make use of the STC experience of desirable outputs to ensure that the development started off in the right direction. Thus, by the critical examination of the STC outputs that already existed, the basic outputs were decided very quickly. One important decision that resulted from this approach was that changes should be monitored at a very high level within the TXE4 documentation system; namely, rack, SIU, tester, and cabling. It was also possible to improve considerably on the original documents to take account of the different needs of BT as an operating business compared with STC as a manufacturer. The improvements were largely at a very detailed level, but 6 are worthy of note;

(*a*) details of whether changes are non-retrospective, partially-retrospective or fully-retrospective were added to the CDB,

(*b*) the unit/rack history listing is sorted by CSI rather than the STC system of using the change note number issue date,

(*c*) the information on related changes is more related to the technical restrictions on compatibility within any individual exchange rather than the logistics of controlling the gradual rise of issue levels of manufacture,

(*d*) information on change notes is added at an earlier stage to give advance notice,

(*e*) unlike the STC equivalent, the CDB off-line report known as *CFS101* shows the change details for all equipment issue levels, and

(*f*) change note and equivalent works specification details are linked (and this will, in time, include ordering code changes).

Resource Requirements

There are 2 aspects to resource requirements; namely, those needed to set up the CDB and those needed to maintain it. The initial development effort required to set up the CDB was approximately 1·5 man-years of engineering time and 0·75 man-years of clerical time, and the computing cost was some £10 000 (equipment hire and mainframe charges). It is expected that the resources needed to run the CDB each year, based on the present policy of minimum change to TXE4, will be about 0·3 man-years of engineering time, 0·5 man-years of clerical time and computing costs of £10 000. These latter figures are, however, very dependent upon the rate of change to TXE4 and the demands for additional outputs or facilities.

Against the costs must be weighed the benefits. There will be time savings throughout BT because the information becomes so readily available and so easy to manipulate. There will be savings for the staff in BT specification standards and works specification groups because of the ease with which Specifications TE9500, TE22000 and TE24000 can be revised. In addition, the reduced lead-time for the updating of specification TE9500 will aid the speedy agreement of change implementation with the manufacturers.

Within BT, information from the CDB is obtained strictly on-demand; that is, there will be no automatic distribution. Specifications TE22000 and TE24000 have ceased to be published and the internal distribution of TE9500 will be drastically reduced. The masters for TE9500 are now print-out from the CDB. Various standard outputs have been made available from the CDB by Compatibility Control and, as a standard feature, any RAMIS database provides sufficient information on its structure for users to extract any other outputs that they think useful.

The whole concept is one where up-to-date information is available for those who wish to use it, but no resources are wasted on automatic distribution.

Only the broad features of the Compatibility Control operations that affect Regions/Boards will be published in a suitable instruction. Detailed information on the output facilities and contents of the CDB is held as an integral part of the CDB. Experienced users are able to access the CDB proper without the need to work through this initial guidance.

Above all, the CDB is flexible to the rate of change of TXE4 as a system. If the TXE4 system changes very little then the CDB costs very little to maintain, but if changes

did occur frequently, the information on the CDB could easily be updated accordingly.

User Participation

For the CDB to be effective and justified it was considered essential to obtain the maximum of user participation during the development phase. For this reason a good deal of publicity was given, particularly in the early stages, to Compatibility Control's desire to accommodate all worthwhile uses.

Selected Regions were approached to check on the need for the CDB before any work began. In mid-November 1982, the CDB was then thrown open to inspection by anyone within BT so that compatibility control could be sure that the data held and the standard outputs provided met the needs of the users. Finally, the complete CDB was available from 1 January 1983 until its operational date of 31 March 1983 for any remaining improvements to be carried out and the data to be validated.

Structure

A RAMIS database is made up of a number of files. It is the structure of these files and the connections between them that determines the efficiency of the database in providing the required outputs. Each file has an inverted-tree structure, with branching out possible on each level. Within a level of a particular file there is a one-to-one relationship between the various items of information held. For example, in the file *ITEMS* any particular UNITCODE may be fitted in a number of different rack types, but each UNITCODE or RACKCODE would only have one category. Items of information on the same level are held in separate fields.

To be efficient on storage requirements, a database must minimise any duplicate storage of information; this tends to favour putting all data into a single file. The efficiency of producing outputs is, however, clearly dependent upon the quantity of information that has to be processed to produce the outputs; this favours splitting the information between a number of files.

Another disadvantage of holding all data in one file is the complexity that this would create when an item branches independently to 2 other items. This is probably best understood with a simple example and by reference to Fig 1. TEXT for a particular WORKSPEC may consist of several entries (each of 80 characters), and similarly there will be more than one pre-release trial LOCATION for a particular WORKSPEC. If TEXT was actually held in file *CHANGES*, it would be necessary for LOCATION to be linked to all TEXT entries for the appropriate works specification.

With a RAMIS database it is possible to satisfy all criteria by the use of virtual levels (shown as (V) in Fig. 1). Each time information is put into the CDB, compatibility control sets up the pointers that link the real information to its virtual levels. In this way, information can effectively be in 2 or more files at once. RAMIS can produce outputs by accessing independent information in different files, but the use of virtual levels greatly improves the efficiency of output production.

Four types of database structure listings are available to all users of a RAMIS database—the list of all files, and individual file listings of description, index and virtual linkage attributes. Between them, these listings supply such factors as the level, name, storage format, and description of each category of information held. It would be impossible to show or explain in this article all of the information contained in these listings for the CDB. Fig. 1 does, however, show the essential structure by giving fieldnames and their levels.

The *TE9500* file is, in practice, only one of 3 interconnected files which together hold the total information on the breakdown of TXE4 ordering codes. The other 2 files are

FILE: *ITEMS*

FIELDNAME	LEVEL	REMARKS
UNITCODE	1	
DATAISSUE	1	Note 1 (Date)
UNITCAT	1	Note 2
RACKCODE	2	
RACKCAT	2	Note2

FILE: *CHANGES*

FIELDNAME	LEVEL	REMARKS
SPLASHNO	1	
SPLASHDATE	1	Note 1
REFERENCE 1	1	Note 3
REMARKS 1	1	
IMPLEMENTBY	1	Note 4
RETRO	1	Note 8
EML	1	Issue
ALLOCDATE	1	
DRAFTISSD	1	
FINALISSD	1	
EMLDATE	1	
FNSCHED	1	
WORKSPEC	2	
REFERENCE2	2	Note 5
REMARKS2	2	
PRIORITY	2	Category
FINALTYPE	2	
CHECKRETURN	2	
DATEISSUED	2	
TEXT	3(V)	
LOCATION	4	) Pre-released
DATESENT	4	) trial
PRTRETURNBY	4	) details
PRTCOMPLETE	4	)

FILE: *HISTORY*

FIELDNAME	LEVEL	REMARKS
EQUIPCODE	1	
DATAISSUE	1	Note 1 (Date)
RACCKC1	2(V)	
RCAT1	2(V)	
SPLASHNO	3	
RIPPLENO	3	
COMMENT	3	Note 7
OCS	3	Note 9
CSI	3	
REFERENCE1	4(V)	
REMARKS1	4(V)	
IMPLEMENTBY	4(V)	
RETRO	4(V)	
EML	4(V)	
ALLOCDATE	4(V)	
DRAFTISED	4(V)	
FINALISSD	4(V)	
EMLDATE	4(V)	
FNSCHED	4(V)	
WORKSPEC	5(V)	
DATEISSUED	5(V)	
TEXT	6(V)	

FILE: *SPECTEXT*

FIELDNAME	LEVEL	REMARKS
WORKSPEC	1	
DATAISSUE	1	Note 1 (Date)
TEXT	2	

FILE: *TE9500*

FIELDNAME	LEVEL	REMARKS
SECTION	1	
DATAISSUE	1	Note 1 (Date)
ISSUE	1	Letter
TITLE	1	Of section
RACKCODE	2	
RACKLAYOUT	2	Drawing number
RPSLAYOUT	2	Drawing number
CONTENT	2	Of section
ILF	3	Ordering code
NOTES	3	
FREEZELEVEL	3	
DIFF	3	Note 6
DIAGRAM	4	Of SIU
UNITCODE	5	
DESCRIPTION	5	
CCTUNIT	5	Number of circuits/SIU
PART	6	Part number of RPS
QUANTITY	6	Of SIU

SIU: Slide-in unit

Notes: 1 See 'CDB issue control'
2 This splits equipment into a category according to the type of exchange in which it can be found, that is:
A for TXE4A only; B for TXE4 RD only; C for either TXE4A or TXE4 RD; and I for mixed TXE4 RD/4A (interworking equipment)
3 Reference to related change note(s)
4 Defines BT and/or manufacturer
5 Reference to related works specification(s)
6 Highlights new ILF codes
7 Relates to individual ripple number, but will also be used to reference Notes
8 N for non-retrospective, P for partially-retrospective, and F for fully-retrospective
9 With indication of when a new PWB layout is introduced

FIG. 1—Basic file structure of TXE4 compatibility database at December 1982

called *SOFTWARE* and *EQPTSPARES*. By the summer of 1983, these 3 files will be linked to the remainder of the CDB to indicate when ordering code changes are associated with discrete change notes. It is also planned that the *CHANGES* file will be augmented by the spring of 1983 to include dates when manufacturers introduce changes into production either by the rework or the clean build of an item.

Ease of Access

One of the key advantages of the CDB is that the information is available throughout BT (and may become available to the manufacturers as well depending on various commercial and security considerations) to anyone with access to the IBM 3081 at Harmondsworth and the ability to specify the procedure RAMIS. After connection to the computer, access is obtained with one command. Such ease of access is crucial because of the wide range of users on maintenance, planning and works duties throughout BT.

Another problem that arose during the creation of the CDB was that of maintaining access for users while Compatibility Control was adding considerable extra data and producing new/revised output options. To overcome this problem, a duplicate set of output instructions was used to produce new/modified instructions, with a quick copy operation when the changes were finalised. Also, data was not added directly into the CDB, but loaded first into datasets either on the IBM 3081 or on Compatibility Control's SBC. It was then a relatively easy and quick process to add the extra data to the CDB during suitably quiet periods.

Outputs

It was decided that the output requirements of users fall into 2 distinct categories; namely, requests for bulk data with no need for immediate availability—best met by an off-line system where printing is carried out by the high quality laser-printer at Harmondsworth and received by the user in approximately 2 days, and requests for limited up-to-date information where immediate availability is desirable—best met by an on-line system.

Table 1 shows the off-line system most of which was available at the 1 April 1983 launch date of the CDB. Table 2 shows similar detail for the on-line system.

An important design difference between reports from the 2 systems is that the off-line report system requires a 132-character line width, while the on-line reports have been restricted to 80 characters. The latter is essential to cater for the many visual display units and printers in use within BT, which may be capable of only this line width.

Off-line reports are requested in normal IBM time-sharing option (TSO) command mode. In several cases, the off-line

TABLE 1
Off-Line Reports

SYSTEM	COMMAND	DESCRIPTION
Compatibility File System	CFS101	Historical change details for SIUs and rack codes by rack
	CFS102	Rack-to-rack compatiblility
	CFS103	The latest PCS of SIU and rack codes by rack
	CFS104	Information by change note number
	CFS105†	Lists of related changes (change notes and works specifications)
	CFS106	Historical change detail by rack and SIU codes
Parts List System	PLS101	The racks on which SIUs can be found by SIU codes
	PLS102	The SIUs which are mounted on racks by rack code
Specification File System	SFS101	A complete Specification TE9500
	SFS102	A specified section of Specification TE9500
	SFS103	A print-out of works specification information (previously Specification TE22000/24000)
		Complete print-out of all SIU quantities contained in an exchange equipment specification:
	SFS104†	(*a*) requires specification to have been processed through the computerised exchange specification system
	SFS105†	(*b*) requires the creation by the user of a dataset of the input data on the IBM computer
	SFS106*	A list of those modifications that are necessary to ensure compatibility between exchange equipments of 2 defined issue states

Notes: † available by 8/83
* available by 4/84

TABLE 2
On-Line Reports (Interactive Enquiry System)

COMMAND	INPUT	OUTPUT
RAMIES1	TXE4 RD circuit diagram	Racks on which the circuit is used
RAMIES2	TXE4A circuit diagram	Racks on which the circuit is used
RAMIES3	TXE4 RD diagram/part	SIUs in which the diagram is used
RAMIES4	SIU code	TE9500 details
RAMIES5	TXE4A diagram	SIUs in which the diagram is used
RAMIES6	TXE4 RD diagram/part	SIUs in which the diagram is used
RAMIES7	ILF code and quantity	Total numbers of each SIU specified
RAMIES8	Section number	TE9500 details
RAMIES9	ILF code	TE9500 details
RAMIES10	Works specification number	Current progress details and equivalent change note
RAMIES11	Rack code	Off-line report CFS101 information
RAMIES12	Rack code	Off-line report CFS103 information
RAMIES13	Change note number	Off-line report CFS104 and CFS105 information
RAMIES14	Rack or SIU code	Off-line report CFS106 information
RAMIES15	SIU code	Off-line report PLS101 information
RAMIES16	Rack code	Off-line report PLS102 information

reports are available with options such as the type of data required—TXE4 RD, TXE4A or mixed TXE4 RD/4A, or on the type of changes which are of interest—all or only retrospective changes. On-line production of these reports is discouraged because of the time needed for printing, the high cost, the possiblity of errors because of line noise, and the inferior.print quality compared with the laser printer. If the reports are needed urgently, they can be produced on-line by entering RAMIS and using the procedure name (as quoted in the appropriate HELP statement) for the report request.

Three off-line reports deserve particular attention:

(*a*) Reports SFS104 and 105 produce lists of ordered SIUs. These lists are essential for TXE4 stores orders. Without the creation of the CDB, the production of these lists would have been a very onerous task and very prone to errors.

(*b*) Report SFS106 reduces considerably the number of works specifications which need to be considered for implementation before an extension (DL or contract) is installed.

Compatibility between any equipments can be judged by manual interpretation of the information in reports CFS101 and 105, but report SFS106 is a much more efficient method if many different equipment types are involved. A variety of options will be available to input the current exchange equipment and extension equipment issue positions in different terms. This enables Regions to make maximum use of SFS106 whatever their policy on keeping records of exchange equipment modification levels.

On some occasions, users will require a hard copy of the on-line report information, but may not have a printer available. In these cases, off-line print-out can be requested.

Initially, it was hoped that the command for all reports could be made meaningful, but character length limitations made this impossible. To assist in the location of the required report, the off-line options have been split functionally into a number of different systems. When the pattern of requirements for on-line options becomes clearer, these too will be split into a number of logical subdivisions.

The CDB has been organised so that users can write (or at least hold a copy of) their own output procedures as an integral part of the CDB. In this way it is hoped that compatibility control can adopt for national usage any extra options which are found to be particularly useful. This will help to maximise the benefit to BT of the time spent developing these new outputs.

Issue Control

A difficult problem to solve with any data held on a computer, and particularly for the quantity of information contained on the CDB, is the question of issue control. How is a user to know whether the information that he has accessed has changed since last inspected. The solution chosen was to keep a record of the last revision date against the first level of information in each file, that is, UNITCODE in the *ITEMS* file, EQUIPCODE in the *HISTORY* file, SPLASHNO in the *CHANGES* file, WORKSPEC in the *SPECTEXT* file, and SECTION in the *TE9500* file. On any access to the CDB, a user may obtain an off-line output giving the latest revision date of all appropriate levels on the CDB. In addition, any complete print-out of TE22000 or TE24000 will contain a sheet which lists the latest revision dates for every works specification in the output. Future developments will give latest revision dates on on-line outputs and asterisk changes since the user's last request for off-line outputs.

Security

The manpower invested in the construction of the CDB is considerable. For this reason, it is essential that the CDB has adequate security against corruption or even complete loss. Password protection is, of course, used, but this is generally regarded as protection only against purely accidental damage. The CDB is, therefore, regularly archived to ensure that a back-up is readily available. As an additional safeguard, it is hoped to hold the data on the CDB in datasets on a removable hard-disc unit, which is part of Compatibility Control's own SBC system.

A new CDB could be created, if necessary, from this locally held data, by the use of a standard COMMS (communications) facility and access to the IBM 3081 at Harmondsworth over the telephone network. If possible, arrangements will be made to allow direct loading of the information from the hard disc because of the time it would take to transfer the data even at 1200 baud.

Design for Beginners or Experienced Users

When the CDB was first launched, all users were inexperienced and required considerable assistance to effect satisfactory access to information. In addition, it was clear that new users could require such assistance at any time in the future. On the other hand, those users who acquired considerable experience of the CDB would justifiably object to the delays that obligatory messages would bring. Several steps have been taken to solve this problem.

The outputs available from the CDB can be listed or not as desired. There is a HELP statement available for every standard output. These HELP statements provide details of the command syntax to obtain the required output, a description of what the output contains, the interpretation (where appropriate) to be employed when using the output, and a history in the HELP statement to indicate when major changes took place in the output's content or interpretation. A general HELP statement is also provided which gives key RAMIS information to aid the user of the CDB who is not very familiar with RAMIS. In addition, there is an output available which provides a *Beginners Guide to the TXE4 CDB*. This guide includes a copy of all current HELP statements and example outputs.

MANAGEMENT STATISTICS

Holding the essential data on TXE4 configuration on an SBC and a mainframe computer makes available powerful sort and display facilities. These are used to produce the outputs already described. There is, however, an added advantage in the ability to produce useful management statistics to fulfill many varied needs; for example,

(*a*) details of change notes issued where document packages are not yet complete,

(*b*) average time between issue of a final change note and availability of the complete package, and

(*c*) the number (or list) of change notes issued, but not yet implemented, either by rework, or retrofit, and/or by clean build manufacture.

ACKNOWLEDGEMENTS

The author wishes to record his appreciation of the efforts of all members of his group who helped to convert the ideas expressed in this article into the reality they are today.

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The Fifth International Symposium on Subscriber Loops and Services—ISSLS 82

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This article reviews the fifth International Symposium on Subscriber Loops and Services—ISSLS 82—held in Toronto, Canada, in September 1982.

The Fifth International Symposium on Subscriber Loops and Services (ISSLS) was held in Toronto, Canada, from 20–24 September 1982. The event, the latest in the biennial series run by the ISSLS Council, was aimed once more at exploring a wide spectrum of topics concerning the advance of technology in local telecommunications. The growth in international standing of ISSLS over the past decade and its status as the foremost forum for presentation and discussion of local-loop issues was reflected in the attendance of nearly 800 delegates from some 25 countries of the world. The papers scheduled for presentation, which numbered 48, covered aspects of service, loop administration and support, evolutionary strategies and, of course, systems and technology.

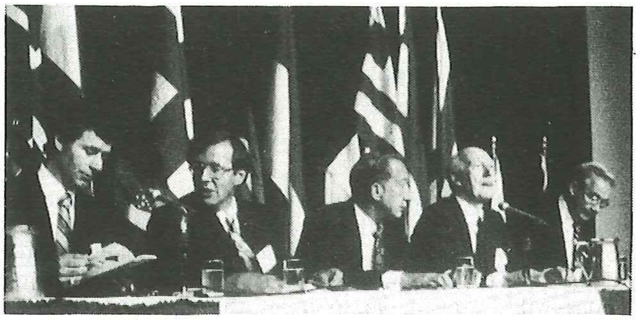
In his opening remarks Bert Hare, British Telecom (BT), Chairman of the ISSLS Council, reviewed the factors which had contributed to the polarisation of interest in local telecommunications. He believed that these were the convergence of computer and telecommunication system techniques; the rapid advances in device technology; and the complementary advance of digital techniques in processing, switching and transmission. The benefits of such advances, already apparent in main networks, were being increasingly sought in local loop and customer equipment; thus, in this sector, issues were very live.

In his keynote address, Gordon Inns, Bell Canada's marketing executive, identified the access network as the focal point of conflict between the expectations of customers and the abilities of operating administrations to provide services. He believed that the challenge lay in exploiting a ubiquitous resource more effectively in an environment of increasing variety of demand.

In the opening technical sessions on new services and customers' requirements for access, the first major impression, later to be fully emphasised, of the dominance of digital transmission technology emerged. Bell discussed their plans to introduce 56 kbit/s plant to meet increased data transport demands and favoured switched rather than private circuit access. A Japanese contribution described plans for an 88 kbit/s local system as part of a move towards an integrated network aimed at offering a total service capability. Digital customer access was identified as an urgent objective and was explored in a modelling technique from Sweden.

The hardening view in Europe towards 144 kbit/s as the eventual transmission standard could see some early digital systems overtaken, including Bell's planned 56 kbit/s speech/data offering. However, the digital systems provided before standardisation were hoped to give advance feedback on the prospects for commercial services.

The second major impression—the interest in the concept of an integrated services digital network (ISDN)—emerged when a provocative paper from Philips, Hilversum, queried the whole basis of what was described as a 'frozen concept' and proposed as an alternative, an integrated services access system confined to the local loop.



At the opening session of ISSLS 82—(left to right)
W. J. Noll (Bell Canada), Admin. Chairman; R. E. Mosher (A T and T), Tech. Chairman; and Messrs. Inns, Hare and Fahey.

In a paper addressing narrowband service provision in the home, Bell Canada's marketing chief quoted predictions that 30% of North American homes would have some form of intelligent terminal by 1990, and described his company's plans to develop a hybrid network to meet the data transport requirements.

For the first time, ISSLS devoted a session to local area networks (LANs). The 3 papers, one from the General Electric Company (GEC) plc emphasising the role of the PABX, one from France describing the CARTHAGE project, and a General Telephones and Electronics (GTE) submission discussing the carriage of telephone traffic on a carrier-sense multiple access network, gave contrasting viewpoints. From the evidence presented, it seemed doubtful if a packetised LAN system aimed at data transfer would be a very effective medium for voice traffic.

Predictably, several session topics featured the application of new technology; these covered the design of customer access systems, line systems and terminating equipment.

Debate continued on the alternative means of achieving digital transmission on the customer's metallic pair. One viewpoint, supported mainly by the European delegates, was that echo cancellation, with its theoretically superior capability but greater circuit complexity, would be the ultimate choice. But Bell had chosen burst mode for their new data service, and Japanese proposals also included this approach. Could this be because microchip devices were readily available?

The interest in emerging plans for the implementation of ISDN facilities was well covered, not only in a specific session on transition aspects, but in related discussions throughout the Symposium. There was a detectable difference in American and European attitudes towards the objectives and in the projected rates of implementation of the appropriate network structures. One strong viewpoint was that the real aim should be to offer digital access to the customer for a variety of services, but basically over current networks; separate service networks could still be the most

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efficient solution for specific groupings, and possibly the only really viable sector for service integration might be the local loop. The 2 most likely future commercial service groupings, telephony and entertainment TV, seemed the most obvious candidates for a 2-network strategy. The doubters were reminded, however, of the ubiquity of the existing telephone distribution system and its potential for common control of all services. The opposing stances of the cable TV industry and the telephone carriers were crystallised when a member (American) of the former, contending that the ISDN did not include any money-making services, bluntly asked when the telephone industry would surrender, since most information services could ride on a cable TV network. The response, loud and clear, spearheaded by Yeates, of Bell Canada, was that the telephone companies would compete (successfully) in all markets. BT to take heart!

The sessions on management of local plant included the preparation of existing plant for digital services, pair gain systems as tools for relief and provisioning, and the problem of modernising existing plant. Papers on multi-pair digital systems highlighted Bell's commitment to their SLC96 system, the added line cost for which appeared expensive for potential UK application. Bell, of course, saw such systems as a move towards their digital service integration. Northern Telecom presented their DMS 1A successor, with digital switch integration, but cost savings were difficult to assess. Progress was described in Bell Canada's urban distribution plant modernisation programme, based on serving area concepts (BT adopted this philosophy many years ago). It included a topical update of the Toronto area which confirmed the cost effectiveness of the concept and, particularly, the benefit of selecting specific areas for modernisation. A paper presented by the American Telephone and Telegraph Company (AT and T) reported much the same.

Not much was said on spare plant levels at relief, although Bell quoted 15%. Against this, BT's 1978 figure of 30%, falling to a current 20%, makes an interesting comparison.

Maintenance interest hinged on a paper from Bell and one from BT; these highlighted the difficulties of maintaining, let alone improving, underground plant, particularly in the distribution sector. In an age of complex electronics, we were reminded of the need, still, for simple reliable devices such as closures for polyethylene cables. Predictably, most delegates kept a discreet silence about the reliability problems that their administrations faced in places such as the tail-ends of the networks.

However, pointedly, there were several papers covering network testing. Although these addressed the preparation of local loops for digital working and emphasised centralised mechanised test facilities, the relevance of and the need for ready commercial equipment for operational support of existing networks was clearly in mind. The marrying of software, stored-program control and measurement technology in flexible and modular support systems was typified by the paper on 4 TEL equipment from Teradyne.

ISSLS has, of course, a fundamental interest in local network evolution, and perhaps the last specific impression was of the extent to which forward conceptual thinking is being based on optical-fibre systems. In the debate on future wideband capabilities, the use of the fibre medium is now implicit. The 5 final papers included one each from France, Germany and the UK, which featured the provision of interactive video and broadcast entertainment services in various degrees of integration with other services. A Japanese paper on a system feasibility trial also predicted applications in business and residential communities. At this stage the systems are, in the main, being field trialled while the problems of producing cost-effective systems are addressed. No one claimed that this had yet been achieved in comparison, say, with other media, but expectations were high.

In the opening presentation, the Toronto General Chairman, Jim Fahey, of Bell Canada, hoped that the Symposium would prove to be an eventful milestone in a fast developing area of technology. This was certainly the case. It recognised, probably more than ever previously, that the market place would be the decisive factor in the progress in the local loop towards new services and facilities. It accounted for the critical scrutiny of new concepts and the down-to-earth sceptism afforded to any designs that were not economically viable. It also sounded the alarm that in reaching towards new concepts of integration, crucial issues of standardisation and protocol needed to be addressed and resolved—urgently.

The ISSLS Council gave its best-paper award to a research group from California University, who had built and evaluated devices to demonstrate the feasibility of a single metal-oxide-semiconductor large-scale integrated device which would implement all the functions of a hybrid-mode digital local transmission system.

The full technical proceedings of ISSLS 1982 are recorded in IEEE Catalogue No. 82 CH 1686-5.

The next ISSLS will be held at Nice from 1–5 October, 1984.

Book Review

Energy in Electromagnetism. H. G. Brooker, Peter Peregrinus Ltd. xiv+360pp. 88 ills. £25·00.

Conventional texts on electromagnetics usually begin with a discussion on electrostatics and magnetostatics, and continue with time-varying fields and Maxwell's equations. Then, when this material is fully established, the concept of electromagnetic power flow through a surface is introduced. Finally, these ideas are brought together in order to develop the energy budget for the electromagnetic field, and the concept of electromagnetic field momentum. However, the author's style, which is radically different to that of others who have written on the subject, has made this a unique book. All the material that one might expect to find in a conventional text is contained in the book, but the order and emphasis is different.

In the early chapters the author covers all the usual topics associated with electromagnetic fields in free space and matter. However, in this treatment the author includes novel concepts such as electromagnetic fields as aggregates of elementary inductors and capacitors, and tubes of electric flux in tension that exert sideways pressure on each other. The remainder of the book is devoted to a detailed discussion of stress, energy and momentum in electromagnetic fields, and to specific problems such as energy in oscillating electric circuits, reflection and refraction of electromagnetic waves at a plane interface.

This book is not intended for those who possess little or no background knowledge of the subject. However, those wishing to extend their knowledge would benefit from reading this book, and those with considerable experience would gain much from the author's novel and interesting approach. The author's treatment is for the most part non-relativistic, and hence the material would be well suited to the research engineer.

M. J. Mehler

Centralised Traffic Recording for TXE2 Exchanges

J. SHIPSEY†

INTRODUCTION

During the installation of a large TXE2 exchange in 1981, it became apparent that the provision of 3 electromechanical traffic recorders would be insufficient to enable a complete traffic record to be taken. A search started for either a fourth electromechanical recorder, or an alternative type of recorder. After enquiries had been made, it was discovered that a microprocessor-controlled recorder, developed by British Telecom (BT) Headquarters, was available. This was found to have the facility for remote operation. It was decided to carry out a trial of this aspect to give centralised traffic recording. This proved to be successful and has been extended to all other TXE2 exchanges in the Bristol Telephone Area.

DESCRIPTION OF TRAFFIC RECORDER

Electrical Design—Microprocessor Concept

The block diagram in Fig. 1 illustrates the main components of the traffic recorder, together with its external connections.

The heart of the traffic recorder is the central processing unit (CPU) (microprocessor), which controls all operations directed by software. The software (or program) is held in a permanent memory, whereas the counts of busy equipment are stored in a volatile memory.

The keypad is used by the operator to enter data into the traffic recorder to control its operation, such as setting the start times for each traffic-recording period, or to request information, such as the counts of busy circuits for each group. A teletype can also be used to enter data or request information. The displays respond to keypad or teletype commands by displaying both the instruction entered and any data requested by the instruction. Standard access units in the exchange are controlled by the microprocessor and are switched to present the monitoring points to the detection circuits in the traffic recorder.

Physical Design

The traffic recorder is housed in a slide-in unit in the appropriate exchange equipment practice, and is accommodated in a suitable existing rack (see Fig. 2). The unit contains the microprocessor, memory and interfaces to both the user and the exchange. Power is supplied to the unit from a DC–DC converter powered from the exchange −50 V supply and housed separately. The traffic recorder is connected to the DC–DC converter and the exchange equipment by multiway plugs and sockets.

A 12-digit keypad and 2 light-emitting diode (LED) 8-digit numeric displays are mounted on the front plate of the unit and form the interface to the user. There are also 5 LEDs which indicate various alarm conditions on the front panel plate. The printed-wiring cards are mounted in a card frame in the slide-in unit and, depending on the card, plug into either a printed-wiring mother board or a flexible-wired area (see Fig. 3).

The cards that plug into the mother board are the processor-oriented cards and are described below.

† Bristol Telephone Area

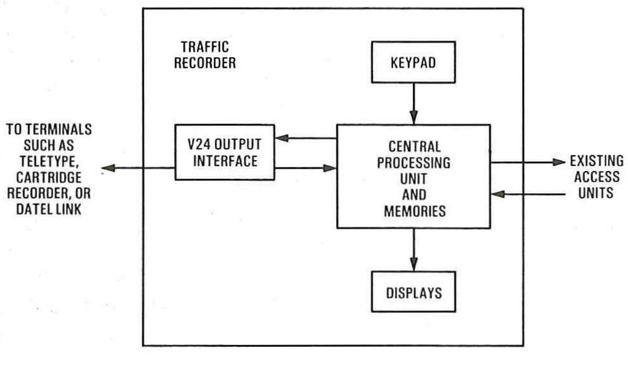


FIG. 1—Main components and external connections of the traffic recorder

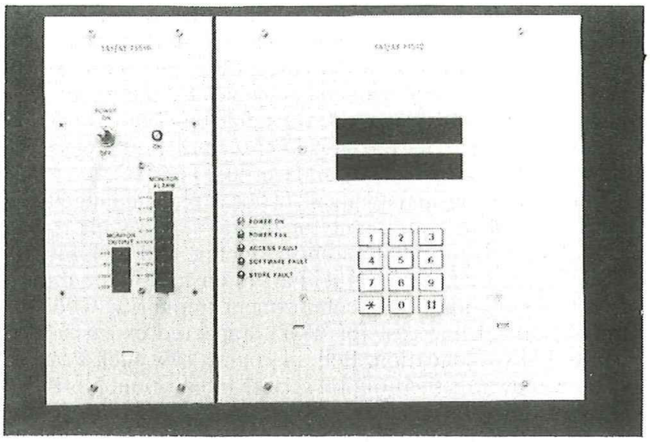


FIG. 2—Front panel of the traffic recorder

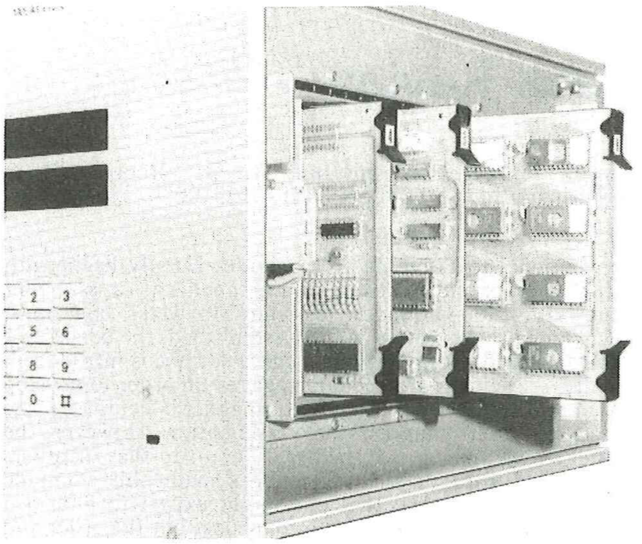


FIG. 3—View of traffic recorder showing card frame and printed-wiring cards

(*a*) *CPU Card* This card contains the microprocessor and its associated buffer and control circuitry. It also contains the universal synchronous/asynchronous receive and transmit (USART) chip, which is an interface device between the processor and a peripheral such as a teletype.

(*b*) *Programmable Read-Only Memory (PROM) Card* This card can contain up to 8 PROM chips in which the program code is stored. For the traffic recorder, 7 PROM chips are required to store the program; also, a further PROM chip, the architecture chip, stores data about the exchange that is relevant to the traffic recorder, including circuit groupings, exchange type, and size of the measurement highway.

(*c*) *CPU Miscellaneous Card* The main elements on this card are the real-time clock, input/output-port decoder, relay-driver-selector port and alarm logic.

The cards that plug into the flexible-wired area are those containing the interfaces between the processor and the outside world; they are described below.

(*a*) *Display and Keypad Cards* There are 2 cards for controlling the displays and keypad; these contain display latches and keypad-interrogation circuits, and interpret data to and from the processor.

(*b*) *Input Interface Card* This card contains 24 operational amplifier circuits, which detect the busy/free potentials on the exchange equipment measurement wires and translate them to the logic levels required by the processor. These circuits also act as high-impedance buffers between the exchange equipment and the processor. Up to 48 detection circuits, made up from a maximum of 2 input interface cards, can be accommodated by the traffic recorder.

(*c*) *Relay Driver Card* This card contains sixteen −50 V driver circuits which, under the control of the processor, operate the access relays in the traffic-recorder access units. A maximum of 12 cards, giving 192 driver circuits, can be accommodated.

(*d*) *Output Miscellaneous Card* This card contains 10 auxiliary earth driver circuits, which can be used in conjunction with the main relay drivers to give a 1-out-of-10 selection, thus enabling up to 1920 relays to be individually operated. It also contains three −50 V relay drivers used for switching access circuits that have to be permanently operated during traffic recording, and a current detector that trips if more than one of the normal access relays are operated simultaneously.

FACILITIES

When the recorder is switched on, or when recording is prematurely terminated, default values, held in the architecture chip, are automatically set for the following:

(*a*) the short-holding-time scan rate,

(*b*) the number of short-holding-time scans per long-holding-time scan,

(*c*) the number of long-holding-time scans per recording period, and

(*d*) the number of days in each traffic or cumulative recording period.

The user can specify his own values for the above 4 items, and the number of weeks between each traffic recording cycle. A maximum of 4 start times can be preset to allow up to 4 recording periods per day. These start times are used both by the normal traffic measurement routine, and by the busy/free analysis routine.

A cumulative recording mode can also be set. This runs only once a day, for the number of days specified for each recording cycle. Only at the end of the recording cycle does the automatic print-out occur. Once set, this continues to operate, regardless of whether it is a traffic recording or busy/free analysis run. During normal traffic measurement, there are 2 scan rates at which equipments are measured. These are called the *short-holding-time* scan rate and the *long-holding-time* scan rate.

For normal traffic measurement, all circuit groups are measured at the long-holding-time scan rate; in addition, up to 51 circuit groups can be measured at the short-holding-time scan rate. Furthermore, up to 4 circuit groups can be preselected to have the number of busy conditions on each of their monitoring wires individually counted.

During traffic recording, signals are extended to connect any external traffic recording meters, such as the register call-count meters, to the registers as in TXE2 exchanges. In addition to the normal traffic measurement routine already mentioned, it is also possible to invoke a special busy/free analysis routine. This routine, which operates only on week days in non-traffic-recording weeks, uses the same start times as the normal traffic measurement routine. When operational, the busy/free analysis routine individually analyses the circuits in 4 consecutive access groups during the specified recording period(s) and, at the end of the recording period(s), prints out the identity of the circuits found to be PERMANENTLY BUSY or PERMANENTLY FREE. In the next recording period(s), the next 4 access groups are similarly treated, and so on. It is possible to set the traffic recorder so that it runs automatically, so that it carries out, for example, normal traffic recording once every 4 weeks and, in the 3 intervening weeks, the busy/free analysis routine. The cycle would continually repeat.

At the end of the required traffic-recording period(s), or busy/free-analysis-recording period(s), a signal is extended by the traffic recorder, which requests connection to an output recording device. The traffic recorder awaits an answering signal, whereupon it outputs either the recorded traffic data, or the identity of circuits found to be PERMANENTLY BUSY or PERMANENTLY FREE. The stores are cleared when the print-out has finished.

The recording device can be accessed directly if sited locally, or via a Datel link if at a central point. The traffic recorder waits for up to 10 s if the recording device is switched off or the link is removed during the print-out. If the break is less than 10 s, the recorder continues outputting data from the point at which it left off. If the break is greater than 10 s, the recorder starts the print-out again.

CENTRALISED NETWORK

When the full facilities of the recorder were known, it became obvious that there could be advantages in operating the recorder remotely, using a Datel link. It was decided that the cost of a dedicated link could not be justified, and so, by using a modified Modem 2B to give automatic-answer facilities, access was obtained over the public switched telephone network. With the experience gained at the first site, it was decided to extend the network to all TXE2 exchanges in the Bristol Telephone Area, with the central teletype located in the trunking-and-grading office.

Work started in mid-1982 and by December 1982 all working TXE2 exchanges were equipped with the new recorders. The responsibility for setting and retrieving traffic records was passed from the maintenance division to the trunking-and-grading groups.

PLANNED ENHANCEMENTS

The following enhancements have been planned:

(*a*) At present, register call count meters still have to be read manually. An additional printed-wiring board has been designed; this will total the register calls in the recording period and relay the information with the record over the Datel link.

(*b*) The readings when received at the teletype terminal are, at present, manually transferred to partially mechanised

traffic recording input forms. It is intended to replace the teletype with a small business computer (SBC). This will store the record data on disc and will then be used to produce automatically forms acceptable to Leeds Computer Centre.

THE FUTURE

The following enhancements are to be investigated:

(*a*) Further development work on SBC programs is foreseen to enable the production of quick-look traffic records at the trunking and grading office similar to the planned Strowger fully-mechanised traffic recorder system.

(*b*) The possibility of sending the records on-line from the SBC, either direct to Leeds Computer Centre, or via another centre which accepts on-line data, is to be considered.

(*c*) The use of the SBC for controlling the setting up of the records using an auto-dialler is to be examined. The recording programme would be fed in at the start of each year and control of the programme then passed to the SBC.

CONCLUSION

The introduction of this network has been welcomed by the maintenance division, because they no longer have to make special journeys to switch traffic recorders on or off and read the meters. As some maintenance loads cover several TXE2 exchanges, considerable savings in travelling costs and time can be made.

The extended group analysis and busy/free facility is being used effectively to identify permanently busied equipment, particularly A–B trunks which are otherwise difficult to find, thereby improving the quality of traffic records and service.

The network forms the basis of a truly fully-mechanised traffic recording system for TXE2 exchanges, which can react quickly to requests for additional or special traffic records.

ACKNOWLEDGEMENTS

The author wishes to thank Mr. C. W. Jackson for permission to print some of the content of this article and Mr. C. F. Clarke for the design of the register call-count circuit, and for their help during the installation of the recorders. Thanks are also due to Mr. H. J. Turner for his support of this project.

Installation of a New Telephone Network and MegaStream System for the London Borough of Newham

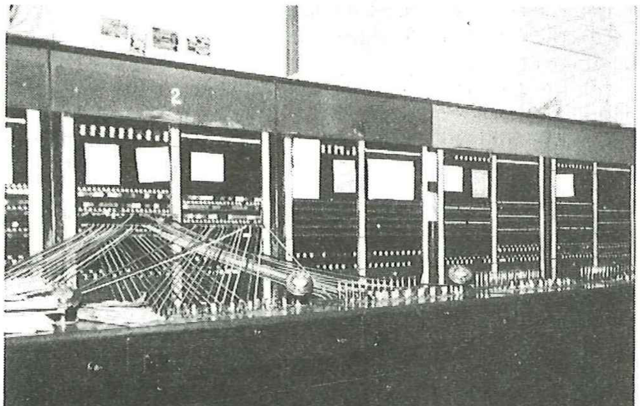
P. BOUSFIELD†

INTRODUCTION

At a meeting with the Sales and Customer Works Group of British Telecom London East (BTLE), the London Borough of Newham stated that they wished to replace their existing fragmented and ageing telephone system with a modern integrated network. The existing system consisted of a PABX4 at Stratford Town Hall with 80 exchange lines and 600 extensions (of which more than 400 were external); a 5-position PMBX1A at East Ham Town Hall with 45 exchange lines and 400 extensions (of which 300 were external); and a private internal exchange, also at East Ham Town Hall, with 350 extensions (of which over 80 were external). The PABX4 was linked to the PMBX1A by 4 inter-switchboard circuits and the PABX4 to the private internal exchange by 14 circuits. The many other offices throughout the borough were served by small switchboards or single exchange lines.

The Borough proposed to integrate the telephone system by installing 2 interconnected stored-program-control (SPC) electronic exchanges in Stratford and East Ham Town Halls and to serve all the outlying offices with external extensions. The exchanges had to cater for a maximum of 800 extensions at each site. The Borough had not decided which of the various SPC exchanges available was best suited to their purposes. BTLE advised the Borough which systems currently on the market were type approved by British Telecom (BT), and which were pending approval, and the characteristics of these systems, especially the differences and advantages of digital over analogue systems.

At a subsequent meeting, on 17 February 1982, BTLE were informed that a contract for the installation of 2 Plessey PDX 800 digital PABXs had been awarded to Telephone Rentals plc (TR). TR proposed to deliver both PDX 800s on 21 May 1982 and hand them over to British Telecom (BT) for commissioning at the end of July 1982. On that



Old switchboard at East Ham Town Hall

† British Telecom London East

basis a tentative ready-for-service date of 1 October 1982 was agreed.

PLANNING AND INSTALLATION

A network plan was then prepared. The Stratford PDX 800 would serve about 120 internal extensions, about 640 external extensions and 4 inter-switchboard private circuits, giving service to 24 outlying offices. The East Ham PDX 800 would serve about 120 internal extensions, about 520 external extensions and one inter-switchboard private circuit, giving service to 22 outlying offices throughout the Borough. The customer requested 15 inter-switchboard circuits to link the 2 PDX 800s.

At this time, information on BT's new digital X-Stream services (MegaStream, KiloStream, SwitchStream and SatStream) was being made available. It was thought that, with 2 digital PDXs, the Borough might be interested in a MegaStream system to link the 2 PDX 800s instead of the 15 individual circuits proposed. The Borough was given information on MegaStream together with comparative costings for a MegaStream link and individual private circuits. Unfortunately, Plessey had not yet developed their digital interface for the PDX 800. Therefore, a multiplexer at each end of the system had to be included in the costing. The link would give 30 discrete channels: 15 of these would be connected to the PDX 800s as inter-switchboard circuits and 15 would be available for data circuits between Stratford and East Ham Town Halls. For this customer, MegaStream offered a very cost-effective solution, especially since a second MegaStream link could be provided at relatively low cost when Plessey had developed their digital interface. The second link would be used solely for inter-switchboard traffic, releasing all 30 channels on the first link for data circuits between the 2 Town Halls. The 7-month lead time quoted for the MegaStream system fitted in with the ready-for-service date for the whole network. The customer placed a firm order for one 2 Mbit/s MegaStream system with 2 multiplexers and a provisional order for a second when the digital interface for the PDX 800 was available.

Planning of the internal cabling proved to be a very difficult task. The wiring in all the major sites and many of the smaller buildings had either to be replaced or enlarged. Many buildings had insufficient spare cable pairs feeding into them, and, in some cases, new directly-wired local cables had to be installed to link the building to its serving PDX.

The Borough also had plenty of work to do. A new building had to be built at the rear of Stratford Town Hall to house its PDX 800. At East Ham Town Hall a cleaners' tea room had to be converted to make it suitable for accommodating the PDX 800 and associated equipment. Each PDX 800 had to have a gas-powered generator installed in an adjacent room, in order to provide stand-by power in the event of mains-electricity failure. The Borough was to provide metal trunking in many buildings through which BT could run its cables. The Borough also was to provide BT with spot plans, showing the location where each extension was required, for each building.

The Borough official responsible for the new installation had the very difficult task of co-ordinating all the telephone requirements for each department, and for preparing the plans. In an organisation as diverse as the Borough, this proved to be a major problem; on several occasions the Borough increased its telephone requirements.

The total time it would take to install all the internal cabling and to fit telephones in all the buildings was estimated at about 4000 man hours. The installation work was started in the second week of August 1982.

The MegaStream and multiplexers were ready for service by the first week of September 1982. This was the first MegaStream system to be installed in London and the first commercial MegaStream system in the country.

Because the installation of the metal trunking and preparation of spot plans by the Borough were delayed, the ready-for-service date for the whole network was deferred to Monday 13 December 1982.

New switchboard consoles at East Ham Town Hall.

CHANGE-OVER

Although some preparatory work for the change-over from the old system to the new network could be done in advance, the change-over still presented a major organisational problem. On the evening of Friday 10 December 1982, the old system would be working to dial telephones throughout the borough, yet on the following Monday the 2 PDXs had to be in service with about 1700 multi-frequency (MF) extension telephones. Wherever possible the MF telephones were fitted in advance, sometimes in parallel with the existing extension, since it was impractible to fit 1700 telephones in one weekend.

As the completion date drew nearer, the installation work proceeded well. As major problems appeared, they were resolved. Just a few days before the change-over weekend it was discovered that the inter-switchboard circuits had been configured wrongly in the PDX 800 software by TR because of a misunderstanding with the Borough. BT staff rectified the problem in less than a day by reconfiguring the software. By Friday 10 December all the preparations for the change-over had been completed.

On Saturday 11 December the PABX4 at Stratford and the PMBX1A at East Ham were taken out of service. Teams of fitters then went to work recovering the old extensions and fitting the new extensions. Several problems were overcome during the weekend, and by Monday morning telephone service on the PDX 800s was available on about 98% of the extensions. The remaining extensions were brought into service progressively as minor cable faults were cleared or as cables were released when the old equipment was recovered.

CONCLUSION

The Borough was delighted with its new network, and to express their gratitude invited all those involved in the installation to a buffet, during which the Leader of the Borough Council praised BT for its performance in installing such a large network on schedule despite the difficulties encountered. It was an enjoyable conclusion to a very challenging and satisfying job. The London Borough of Newham is now served by an excellent fully-integrated telephone network, which utilises some of the most up-to-date technology at present available, for the benefit of employees and especially all those who have dealings with the Borough.

The Transmission-Relay-Group Routiner at the Luton TXK1 Crossbar Telephone Exchange

A. R. GROOM†

INTRODUCTION

Luton TXK1 crossbar telephone exchange opened for service on 4 July 1979 with 7 routers and a subscribers multiple of 10 000 lines, and since then work has continued on the task of providing more routers and a larger multiple. As the crossbar exchange forms only a small part of a large linked numbering scheme, the crossbar unit deals predominately with outgoing and incoming traffic rather than with own-exchange traffic.

Traffic flows into the crossbar unit via incoming transmission relay groups (TRGs), which are allocated one per circuit and perform call control and supervisory functions. The maintenance of the incoming part of the exchange was a major problem from the very beginning. Manual testing of such a large number of circuits was a lengthy and labour-intensive operation. Customers reported difficulty frequently, but often no cause could be found. It became clear that a method of automatically testing the incoming TRGs was required.

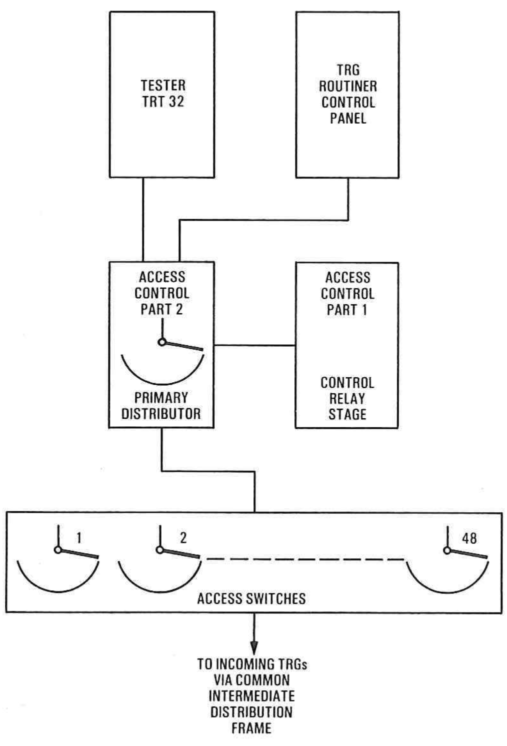
THE TRG ROUTINER

The main aim was to alleviate the service problems by developing a reliable automatic tester in the shortest possible time. The routiner that was developed was therefore based on proven Strowger technology. British Telecom's Tester TRT 32, a very reliable and highly flexible tester offering a basic series of functional tests, was well suited to the project and was therefore chosen as the test unit. The Tester TRT 32 was interfaced with the incoming TRGs by means of an access control and an arrangement of access uniselectors, which were constructed locally and were developed from the access control of Tester 219A—a routiner for testing coin-and-fee-checking relay-sets. A block diagram of the TRG routiner is shown in Fig. 1.

The modifications carried out on the Tester TRT 32 were kept to a minimum to keep the circuit as standard as possible. The 2-part access control and access uniselectors were therefore mounted remotely from the Tester TRT 32 on the exchange meter racks, above the meters, and an auxiliary control panel for the TRG routiner was located adjacent to the Tester TRT 32 in the main end panel of an equipment suite. The incoming TRGs were accessed at the common intermediate distribution frame of the exchange.

The regular facilities of the Tester TRT 32 are not restricted by the addition of the TRG routiner functions. A test call is originated from each incoming TRG in turn to one of 21 answering numbers, and an artificial traffic signal is simultaneously extended to the exchange. This process suppresses various time-outs to aid maintenance tracing; it also cancels the exchange line continuity test, and so allows switchblock faults to be held and traced. The basic functions of the TRG are checked before the call is released.

†Bedford Telephone Area



TRG: Transmission relay group

FIG. 1—Block diagram of the TRG routiner at Luton TXK1 telephone exchange

PERFORMANCE OF THE ROUTINER

The routiner has an ultimate capacity of 48 access switches or 960 circuits. During the period when the routiner was most heavily loaded, it carried 830 circuits on 42 access switches, tested one circuit every 30 s, and found perhaps a couple of faults on each testing cycle. The routiner was started early on a Monday morning and had generally completed the testing cycle, with all the faults cleared, by Tuesday evening; for the rest of the week the Tester TRT 32 was run in one of its other modes. Some of the access switches have now been off-loaded on to a second routiner, which has been provided to cater for the introduction of further routers; this has reduced the cycling time still further.

A major problem which was quickly identified on a number of incoming TRGs was the transposition of certain resistors by the manufacturer, a fault which caused a resistance P-wire condition and which resulted in call failures only on certain routeings. This fault, though obscure, affected service, and had evaded completely tests carried out with manual testers.

Since it was brought into service, the reliability of the TRG routiner has been extremely good and no faults on the locally constructed equipment have occurred.

CONCLUSION

This has been a very worthwhile project. The routiner has located over 100 faults on common equipment, the switchblock and the incoming TRGs, and has contributed to a substantial improvement in service at Luton.

ACKNOWLEDGEMENTS

The author would like to thank Mr. A. Britchford and Mr. B. Wheeldon for supporting the project, and all the people at Luton Telephone Exchange, too numerous to mention individually, who were involved in its realisation.

Institution of British Telecommunications Engineers

(formerly Institution of Post Office Electrical Engineers)

General Secretary: Mr. R. E. Farr, TE/SES5.3, BT Research Laboratories, Martlesham Heath, Ipswich IP5 7RE; Telephone Ipswich (0473) 644803
(Membership and other local enquiries should be directed to the appropriate Local-Centre Secretary as listed in the October 1982 issue)

SUBSCRIPTIONS TO THE INSTITUTION AND TO THE FEDERATION OF TELECOMMUNICATIONS ENGINEERS OF THE EUROPEAN COMMUNITY (FITCE)

No changes are contemplated to annual subscriptions for 1983/84 and these remain as follows:

Corporate Members of IBTE	£3.96	
Non-Corporate (Corresponding) Members	£6.00	
Commuted subscription for retiring Corporate Members	£8.00	(once-and-for-all payment)
FITCE (existing Members will be approached individually in July 1983)	£5.00	

The Affiliation Fee for independent Associate Section Centres will remain at 2p per member, but the bulk fee paid by the National Executive Committee for all the Associate Section Centres it represents has been increased by Council to £60.00.

AMENDMENTS TO THE RULES OF THE INSTITUTION

Institution Rules concerning the award of Medals have been amended to permit Council to make such awards for presentations which are not accompanied by papers (see note in the October 1982 issue). The changes have been certified by the Chairman of Council as not affecting the intended operation of the Rules in accordance with Rule 33 and became effective on 1 January 1983. The amendments are as follows.

Rule 43 Amend to read:
"It shall be the duty of each Local-Centre Committee to consider all presentations, whether or not accompanied by a paper, given by members at meetings of the Institution held at its Centre, as soon as possible after each presentation, with a view to deciding by vote whether Council shall be requested to take action under one or both of Rules 36 and 46."

Rule 44 (duties of Honorary Local Secretaries) Amend paragraph (a) to read:
"To call for promises of speakers and papers prior to the opening of each session."

Amend paragraph (i) to read:
"To arrange that a report on any presentation recommended by the Local-Centre Committee for the award of an Institution Medal and copies of any paper recommended for printing or the award of a Medal shall be submitted to the Secretary at the end of each session for consideration by Council."

Rule 45 Amend paragraph (a) to read:
"*Institution Senior and Junior Medals.* One Silver and one Bronze Medal to be called 'Institution Senior Medals' and one Silver and one Bronze Medal to be called 'Institution Junior Medals' may be awarded yearly to members for the best presentations, whether or not accompanied by papers, given at meetings of the Institution during the twelve months ended on 30 June of the previous year."

Amend paragraph (b) to read:
"*Institution Field Medals.* Three Bronze Medals to be called 'Institution Field Medals' may be awarded yearly to members for the best presentations, whether or not accompanied by papers, on field subjects primarily of Regional interest. The presentations to be considered for these Medals shall be those given at meetings of the Institution during the twelve months ended on 30 June of the previous year."

Rule 45X (sets out conditions for Senior and Junior awards) Amend all references to "paper(s)", "author(s)" and "read" to read "presentation(s)", "speaker(s)" and "given", respectively.

Rule 46 Amend to read:
"The selection of presentations for the award of Institution Medals from those recommended for consideration by Local-Centre Committees under Rule 43 shall be the responsibility of the Council. In deciding on the award of Medals, Council shall give precedence to those presentations accompanied by a paper. . . . . ."

Rule 46X (presentation at Annual General Meeting) Amend "papers read" to read "presentations given" and "presented" to read "awarded".

Reference copies of the Rules updated to 1 January 1983 are now held by all Local-Centre Secretaries and Members of Council.

MEDAL AWARDS FOR PAPERS PRESENTED IN THE 1981/82 SESSION

Four written papers were recommended by Local-Centre Committees for Field Medal awards. All were of a good standard and, since the Institution's Rules permit only 3 such awards to be made in any one session, the problem was one of selection. Council unanimously agreed to award Field Medals as follows.

Mr. D. Healey, Swansea Telephone Area: *Energy Conservation.*
The judges described this as a well-written paper, presenting an excellent survey of world and UK resources and conveying a message of growing importance to British Telecom.

Messrs. R. Duers and J. W. Smith, BT Midland Headquarters: *Modern PABX Maintenance.*
The judges commented that the paper highlighted problems experienced in the field with the plethora of proprietary PABX systems. The paper recommended ways of balancing the need for a very fast service to important business customers on the one hand while containing staff resources on the other. The interest of the reader was maintained throughout the paper.

Messrs. J. Forss, Coventry Telephone Area, and R. N. Wetton, BT Midland Headquarters: *Home Computers.*
The judges felt that this paper succeeded in removing the mystique associated with small computers by eliminating much of the jargon. Differences between various programming languages were explained and attention was drawn to the possible pitfalls when peripheral equipment is being chosen. The presentation of the paper was supported by working demonstrations in which video monitors were used.

The fourth paper recommended, *System X and You*, by Mr. G. A. Fell, failed to win an award because the judges considered that it did not introduce any original ideas into what was otherwise a sound survey of System X.

FITCE CONGRESS AND GENERAL ASSEMBLY

The 22nd FITCE Congress and General Assembly is to be held from 19–24 September 1983 in Madrid, Spain. Further details can be obtained from the Secretary of the IBTE (the address is printed at the top of this page).

RETIRED MEMBERS

The following members have retained their membership of the Institution under Rules 10(a) and 13(a):

A. C. Anderson	32 East Meads, Onslow Village, Gloucester GU2 5SP
W. R. Anderson	2 Hallam Avenue, Birstall, Leicester LE4 3DN
J. D. Andrews	Capon's Green Farm, Dennington, Woodbridge, Suffolk IP13 8JH
D. E. L. Arnold	245 Westdale Lane, Carlton, Nottingham NG4 4FL
L. W. Bartlett	41 South Rise, Llanishen, Cardiff, South Glamorgan CF4 5RF
C. V. Beardow	34 Ashley Drive, Whitton, Twickenham, Middlesex TW2 6HW
J. Bell	30 Alms Hill Road, Sheffield, South Yorkshire S11 9RS
R. W. Bell	10 The Mount, Yarmouth, Isle of Wight PO41 0RB
C. Bennion	72 Sandy Lane, Sandyford, Stoke-on-Trent, Staffordshire ST6 5LW
D. F. Best	24 Rushdene Road, Brentwood, Essex CM15 9ES
R. Blakey	52 Thistledene, Thames Ditton, Surrey KT7 0YJ
J. Bluring	38 Wanderdown Road, Overingdean, Brighton, East Sussex BN2 7BT
J. L. Bowley	"Mondego", Main Street, Kirby Bellars, Melton Mowbray, Leicester LE14 2EA
G. F. Brookes	10 High Beech, South Croydon, Surrey
R. Brown	45 Bonaly Grove, Edinburgh EH13 0QB
G. A. Buck	14 Belfield Road, Pembury, Tunbridge Wells, Kent TN2 4HL
R. G. Buckland	55 Friars Place Lane, Acton, London W3 7AQ
E. H. Clark	42 Ferney Road, East Barnet, Hertfordshire EN4 8LF
B. M. Clifton	16 Harper Avenue, Idle, Bradford, West Yorkshire BD10 8NU
A. C. Cole	78 Appletrees, Bar Hill, Cambridge CB3 8SW
T. C. Conington	31 St. Mark Drive, Colchester, Essex CO4 4LP
C. R. Crewes	"Rosemount", Watburn Road, New Mills, Stockport, Greater Manchester SK12 4HH
G. C. Crockett	69 Arundel Road, Wordsley, Stourbridge, Worcestershire DY8 5EH
D. J. Croydon	67 Court Avenue, Old Coulsdon, Surrey CR3 1HJ
E. H. Curtis	78 Percy Road, Hampton, Middlesex TW12 2JR
J. Davies	"The Croft", 2 Redstone Close, Meols, Wirral, Cheshire L47 5AL
C. A. C. Deane	78 Harlaxton Drive, Nottingham NG7 1JB
F. W. Dixon	5 Washdyke Lane, Nettleham, Lincoln LN2 2PW
W. T. Duerdoth	Packway Cottage, Kettleburgh, Woodbridge, Suffolk
R. J. Dunn	Castle Garden, Dairy House Lane, Bradfield, Manningtree, Essex CO11 2XB
G. A. Edwards	47 St. Monance Way, Colchester, Essex CO4 4PG
H. Eustace	89 Whitburn Road, Toton, Beeston, Nottingham NG9 6HR
F. G. Finn	23 Church Road, Seal, Sevenoaks, Kent TN15 0AU
A. E. Fischer	11 Rugby Drive, Dresden, Stoke-on-Trent, Staffordshire ST3 4PA
S. Foster	24 Chine Walk, West Parley, Wimborne, Dorset BH22 8PO
J. D. Frew	45 Peppard Road, Caversham, Reading, Berkshire RG4 8NR
R. P. Fry	25 Gatesheath Drive, Upton-by-Chester, Chester CH2 1QU
W. C. D. Gallop	Yew Tree Cottage, Filston Lane, Shoreham, Sevenoaks, Kent TN14 7SP
J. Gannon	High Trees, Old Watling Street, Flamstead, St. Albans, Hertfordshire
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Members about to retire are reminded that they, too, may secure life membership of the Institution at a once-and-for-all cost of £8·00 and so continue to enjoy the facilities provided, including a free copy of this *Journal* posted to their home address.

R. E. FARR
Secretary

Forthcoming Conferences

Further details can be obtained from the conferences department of the organising body.

FORUM 83 Secretariat, International Telecommunications Union, CH-1211 Genève 20, Switzerland.
Telephone: +41-22-995190

World Telecommunications Forum, Part 2, Technical Symposium
29 October–1 November 1983
New Exhibition and Conference Centre, Geneva

Institution of Electrical Engineers, Savoy Place, London WC2R 0BL
Telephone: 01-240 1871

CONFERENCES

International Conference on Software Engineering for Telecommunication Switching Systems
4–8 July 1983
Lund, Sweden

International Conference on Radio Spectrum Conservation Techniques
6–8 September 1983
University of Birmingham

International Conference on Reliability of Power Supply Systems
19–21 September 1983 (Revised dates)
Institution of Electrical Engineers

International Conference on Advanced Infra-Red Detectors and Systems
24–26 October 1983
Institution of Electrical Engineers

The Impact of LSI and VLSI Techniques on Line and Radio Telecommunication Systems
30 November–2 December 1983
Institution of Electrical Engineers

European Conference on Electrotechnics (EURCON)
26–28 September 1984
Brighton
The theme of the conference is to be 'Computers in Communication and Control'

VACATION SCHOOLS

Transmission for Telecommunication Purposes
24–29 July 1983
University of Aston in Birmingham

Data Communication
4–9 September 1983
University of Aston in Birmingham

Software Engineering for Microprocessor Systems
11–16 September 1983
University of Essex

Stored Program Control of Telecommunication Switching Systems
11–16 September 1983
University of Essex

Institution of Electronic and Radio Engineers, 99 Gower Street, London WC1E 6AZ. Telephone: 01-388 3071

Networks and Electronic Office Systems
26–30 September
University of Reading

ISS '84 General Secretariat, Via Aniene, 31, 1-00198 Roma, Italy

ISS '84. International Switching Symposium
7–11 May 1984
Florence

British Telecom Press Notices

BRITISH TELECOM INTRODUCES TABLETOP PAYPHONE

British Telecom (BT) recently introduced a tabletop telephone known as the *Payphone 100*. It is the smallest type of payphone in service in this country and is only 229 mm square, 178 mm high, and weighs less than 3·2 kg. The Payphone 100 can be transformed from an ordinary telephone into a payphone at the turn of a key; in this mode it accepts 2p, 5p, 10p, and 50p, coins, and refunds unused coins at the end of a call.

The Payphone 100 will be particularly useful to owners of small businesses who want to provide their customers with the facilities for making telephone calls but who do not wish to give away free calls. The Payphone 100 will naturally appeal to owners of businesses such as pubs, clubs, wine bars, garages, hairdressers and shops, and to businesses that have only one telephone line, since it can be used either as a private line or as a payphone; thus, some renters of this tabletop telephone will save the cost of an additional line. The Payphone 100 has also been designed for use with BT's new socket system, in which a telephone can be easily unplugged and moved from room to room, wherever sockets are available.

Local, trunk and international calls can be keyed when the Payphone 100 is being used as a payphone, but calls to or via the operator, except for emergency services, cannot be made. Up to 4 coins can be inserted in the payphone at the start of a call, and further coins can be added while a call is in progress. The coins are used in the order in which they are inserted and unused coins are returned at the end of a call. When the Payphone 100 is being used as an ordinary private telephone, full facilities, including operator services such as directory enquiries, fault reporting and calls via the operator, are available without the user having to insert coins.

The Payphone 100 was successfully put on trial in the London area in 1981. Although it has been available only in London, the Payphone 100 is now being introduced throughout the rest of the country; it is manufactured for BT by the Croydon-based company, Aeronautical and General Industries.

The Payphone 100 is the latest addition to BT's family of electronic press-button payphones that have already made their appearance throughout the UK. By the mid-1980s all of the UK's 77 000 public payphones will have been replaced with new electronic models, and 300 000 rented payphones will have been replaced by the end of the decade.

The cost of the Payphone 100 has been kept low by denying the user the facility of being able to make calls to or via the operator when it is being operated as a payphone.

Payphone 100

Those who rent the Payphone 100 will be charged for calls at the normal rate, but those who use it as a normal payphone will have to insert coins at the higher coinbox rate; the renter of the Payphone 100 will retain the extra cash.

The Payphone 100 is available in 3 colours: the surface area can be dark brown, yellow or stone, but the cash compartment at its base is always coloured black.

INTRODUCTION OF MINI BATTERIES

A new method of powering telephone exchanges which could save British Telecom (BT) thousands of pounds is to be introduced this year. Large and costly conventional batteries are to be replaced by compact units that match in size the micro-electronic switching systems they power.

The equipment, which has been developed by BT in conjunction with Chloride Ltd., is known as *power equipment rack (PER)*, and is virtually maintenance free. It is the first long-stand-by system in the world to be introduced as well as the most compact; and it is expected to have export potential.

This new power pack, which converts mains electricity into the low-voltage DC used in telephone exchanges, has been designed to be installed alongside advanced digital exchanges, like System X, or to stand alone as a complete DC power system.

At present BT spends about £5M a year on batteries and PER is intended to save between 20% and 40% in total costs. PER saves money in several ways:

(*a*) No separate power room is needed. PER can be mounted on the same racks alongside the switching equipment, whereas conventional batteries require special ventilated rooms and cumbersome distribution bars to send power around the building.

(*b*) Future needs can be supplied when they are wanted. (Traditional batteries have to be planned for the total eventual capacity of an exchange and provided years ahead, at considerable expense.)

(*c*) Reliability is assured by a modular system, so that power is maintained if one unit fails.

(*d*) Virtually no maintenance is involved and faults are diagnosed automatically.

(*e*) No hazards are present since PER employs sealed batteries which cannot spill or give off fumes (unlike the conventional semi-open lead-acid batteries).

PER has been under development for 2 years and a major installation programme will start later this year. It attracted much attention last autumn at the International Telephone Energy Conference in Washington. All the equipment is contained in a standard-sized equipment rack which contains both batteries and power equipment.

Notes and Comments

CONTRIBUTIONS TO THE JOURNAL

Contributions to *British Telecommunications Engineering* are always welcome. In particular, the Board of Editors would like to reaffirm its desire to continue to receive contributions from Regions and Areas, and from those Headquarters departments that are traditionally modest about their work.

Anyone who feels that he or she could contribute an article (short or long) of technical, managerial or general interest to engineers in British Telecom and the Post Office is invited to contact the Managing Editor at the address given below. The editors will always be pleased to give advice and try to arrange for help with the preparation of an article, if needed.

GUIDANCE FOR AUTHORS

Some guiding notes are available to authors to help them prepare manuscripts of *Journal* articles in a way that will assist in securing uniformity of presentation, simplify the work of the *Journal*'s editors, printer and illustrators, and help ensure that author's wishes are easily interpreted. Any author preparing an article is invited to write to the Managing Editor, at the address given below, to obtain a copy.

All contributions to the *Journal* must be typed, *with double spacing between lines*, on one side only of each sheet of paper.

As a guide there are about 750 words to a page, allowing for illustrations, and the average length of an article is about 6 pages, although shorter articles are welcome. Contributions should preferably be illustrated with photographs, diagrams or sketches. Each circuit diagram or sketch should be drawn on a separate sheet of paper; neat sketches are all that is required. Photographs should be clear and sharply focused. Prints should preferably be glossy and should be unmounted, any notes or captions being written on a separate sheet of paper. Good colour prints and slides can be accepted for black-and-white reproduction. Negatives are not required.

It is important that approval for publication is given at organisational level 5 (that is, at General Manager/ Regional Controller/BTHQ Head of Division level) and authors should seek approval, through supervising officers if appropriate, before submitting manuscripts.

Contributions should be sent to the Managing Editor, *British Telecommunications Engineering,* IDP 5.1.1. Room 704, Lutyens House, Finsbury Circus, London EC2M 7LY.

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Readers external to BT and the PO

Subscriptions for all readers of the *Journal* who are not employees of British Telecom (BT) or the Post Office (PO), either at home or abroad, are dealt with by the Sales department, whose address is *British Telecommunications Engineering Journal* (Sales), Ground Floor Lobby, 2–12 Gresham Street, London EC2V 7AG. However, readers should note that, because this department is staffed by voluntary staff who work on a part-time basis, personal callers cannot be served.

Subscriptions can run for any period of 4 issues; the last issue contains a renewal slip, which should be returned with a remittance for £5·20 if a subscriber wishes to continue receiving the *Journal*. If any queries arise, subscribers should quote the period for which their subscription has been paid. Subscriptions can be made direct or through a bookseller who deals with periodicals.

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These members receive their *Journals* directly by post. The membership list is maintained by the General Secretary of the Institution. If any corresponding or retired member is not receiving his *Journal* regularly or wishes to notify a change of address, he should write to the General Secretary, IBTE, SES 5.3, British Telecom Research Laboratories, Martlesham Heath, Ipswich IP5 7RE, stating his membership category.

Members of the IBTE

Members of the Institution, but not of its Associate Section, receive the *Journal* automatically after joining the IBTE, since payment is covered by the membership fee. Copies are actually distributed by local sales agents of the *Journal*; but the agents merely act on the instructions of the local secretary of the Institution who is responsible for maintaining the membership list. Any member of the Institution who is not receiving copies of his *Journal* regularly should therefore inform his local secretary. A list of all the local secretaries of the IBTE is published every year in the October issue of the *Journal.*

Associate Section members of the IBTE only receive the *Journal* if they pay for it separately by deduction from pay, or by cash; to arrange this they should contact their local sales agent—this procedure is discussed in the next paragraph.

BT and PO members of staff who are not members of the IBTE

Staff who are not members of the Institution can pay for the *Journal* by deduction from pay, or by cash, and receive their *Journal* from *Journal* sales agents. There is a sales agent in every Telephone Area office, and in every BT and PO Regional Headquarters. Usually the agent is situated in a domestic or literature duty. Several agents, in appropriate domestic duties, serve BT Headquarters and there is an agent for the PO Headquarters. The enquiry point in the Area, Region, Division or Department should be able to tell an enquirer the name of the local sales agent. In cases of difficulty subscribers should write or telephone the editorial office for help: the address is British Telecommunications Engineering, IDP 5.1.1, Room 704, Lutyens House, Finsbury Circus, London EC2M 7LY, (Telephone: 01-357 4313).

QUESTIONNAIRE

The October 1982 issue of the *Supplement* included a questionnaire in which readers were asked to give their views on the *Journal* publishing further educational articles which dealt with subjects at a basic level, similar in style to the paper entitled *Field-Effect Transistors,* also included with that issue of the *Supplement*. In addition to answers for specific questions, readers were asked to make comments and suggestions on the proposed scheme. A selection of these is reproduced below.

'For some subjects excellent texts are available from outside sources; for example, Open University course units. There might be some merit in concentrating on

(*a*) those topics for which information from outside sources is not easily available, or

(*b*) those topics which are exclusive to British Telecom, such as signalling or transmission systems used by British Telecom.'

L. J. Bolton

'I feel that this is a first class scheme especially if the format and style of the *Field-Effect Transistors* paper is followed. It is clearly laid out and is written at a level very suitable for students following Technical Education Council courses.'

D. H. Escudier
(South London College)

'I think publication of basic information papers is particularly useful for refreshing and updating those whose day-to-day work does not bring them into regular contact with some of the latest technology at the detailed level.

'Publication in the *Supplement* ensures that they reach the maximum number of those who may be interested and willing to read them but who might not make the effort to

go out and buy booklets; there are many publications already available, if one is willing to make the effort to track them down.'

R. W. Baker

'It is an excellent idea and would fulfil a need of which I have been conscious throughout my career. The *Educational Pamphlets* have attempted to be too much like a comprehensive textbook and, of recent years, they have been outdated (though to be honest I have not recently looked at them). Suggestions for further reading should be an essential part of the new publication.'

C. Johnston

'The first educational paper is very technical, assumes a strong basic knowledge of semiconductor theory, and is probably over the head of many managers. Would it not be better to keep the treatment at the appreciation level, or at least give the background necessary for a full understanding?'

M. Part

'I found the experimental paper on *Field-Effect Transistors* very useful for revision and for broadening technical knowledge. Technical education soon becomes outdated these days, unless one is actively involved in a specialism.'

D. H. Bostrom

'It is a good idea to have these educational papers. Sometimes the content of *British Telecommunications Engineering* is a little too advanced and this idea, I am sure, will help many engineers who cannot cope with the high level of technological explanation.'

D. J. Shelton

'I think it is a very good idea. More simplified articles on specific subjects would be extremely useful for someone trying to gain some knowledge of a new field before attempting to read the more in-depth treatment in a *Journal* article.'

L. Robertson

'The article on *Field-Effect Transistors* is one of the finest I have ever read. If further subjects are treated in the same way, the *Supplement* will be much sought after. Congratulations to all concerned for an excellent production.'

D. S. Bill

'Part of the function of the Institution of British Telecommunications Engineers must continue to be the updating and advancing of the membership's appreciation of new technologies. The addition of educational papers on a regular basis would assist this function. In many cases the writers of papers published in the *Journal* assume certain levels of knowledge of different developments of technology, whereas the majority of readers do not possess such in-depth knowledge.

J. Sharp

'It would be most useful if the educational papers were to complement the model answer *Supplement*; that is, a reasonable proportion of them related to Technical Education Council topic areas. This would further help students studying these courses. Whether you decide to publish these papers in the *Supplement* or in booklet form, I very much hope you will go ahead with the scheme.'

R. K. Winter

British Telecommunications Engineering

Subscriptions and Back Numbers

The *Journal* is published quarterly in April, July, October and January, at 80p per copy (£1·30 per copy including postage and packaging); annual subscription: £5·20; Canada and the USA: $12·00.

The price to British Telecom and British Post Office staff is 48p per copy.

Back numbers will be supplied if available, price 80p (£1·30 including postage and packaging). At present, copies are available of all issues from April 1974 to date with the exception of the April and October 1975; April and October 1976; and January 1982 issues.

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British Telecommunications Engineering

REPRINTS OF

System X

ARTICLES

The 26 articles on System X which appeared in the *Journal* between January 1979 and April 1981 have been reprinted as a single 160-page book. The articles in this book describe:

(*a*) The concepts of System X and its use in the UK telecommunications network.
(*b*) The principles of the system, including aspects related to digital switching, common-channel signalling, and processor control.
(*c*) The individual subsystems.
(*d*) The hardware and software.
(*e*) The design and support of modern switching systems.

The articles were written over a period of 3 years whilst the initial stages of development of System X were proceeding. As a result of advances in technology since the start of development, many significant changes have taken place within the subsystem designs. Specifically, the processor subsystem has been revised to take advantage of new technology, whilst still retaining a multi-processor form. The one processor architecture is used throughout the system family. The overall system concepts and the network applications still remain as described in the articles.

The cost of this book is £3·00 including post and packaging (the cost to British Telecom (BT) and British Post Office (BPO) staff is £1·50).

If you wish to order copies of this book, please complete the appropriate section of the order form below and send it to the address shown. (Cheques and postal orders, payable to "*BTE Journal*", should be crossed "& Co." and enclosed with the order. Cash should not be sent through the post.)

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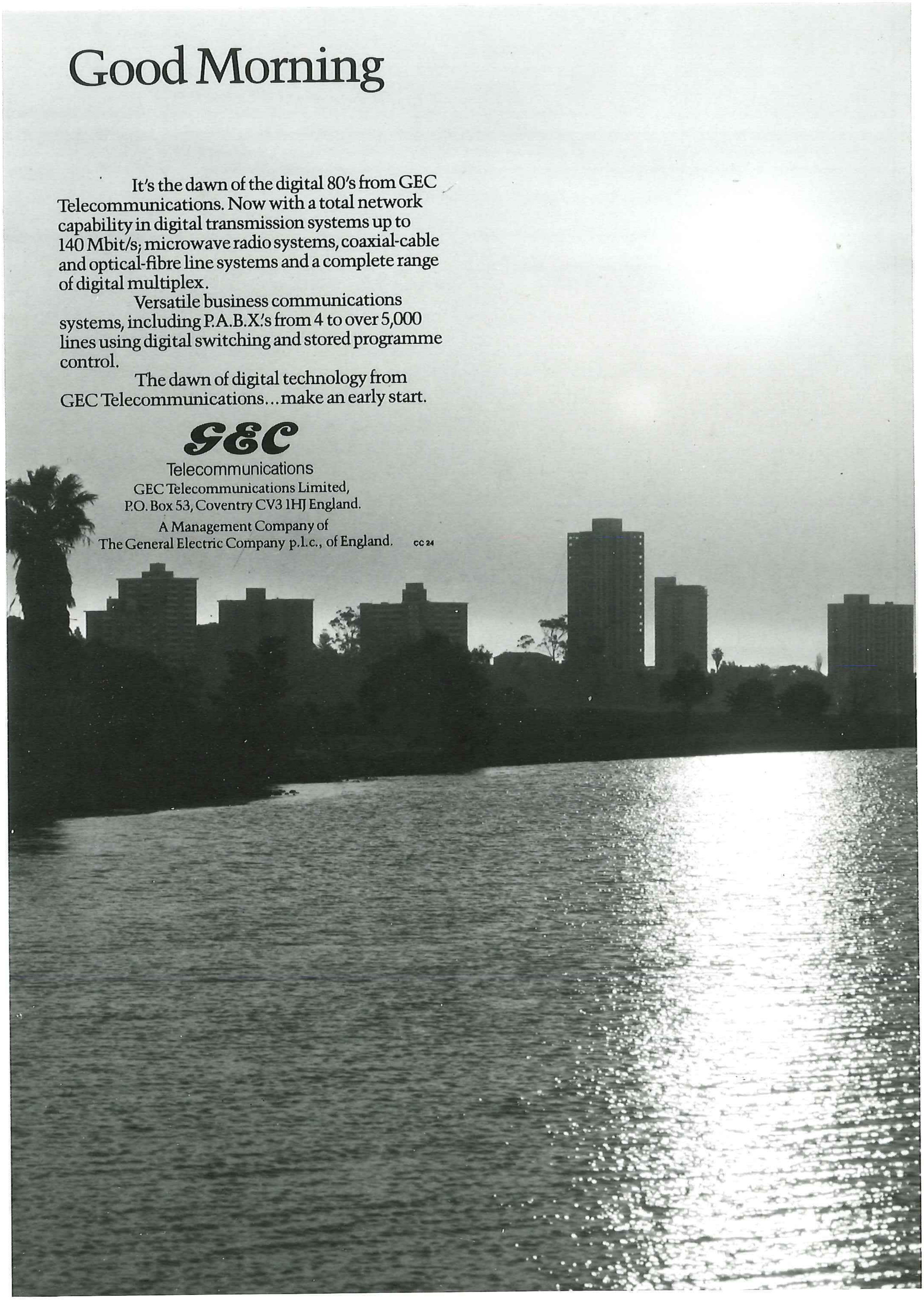
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